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Report of the

ACMRR WORKING PARTY ON THE SCIENTIFIC BASIS OF DETERMINING MANAGEMENT MEASURES

Hong Kong, 10-15 December 1979

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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PREPARATION OF THIS REPORT

This is the report of the ACMRR Working Party on the Scientific Basis of Determining Management Measures, as approved at the Second Session of the Working Party held in Hong Kong, 10-15 December 1979.

It considers the problems of managing fisheries as an integrated subject. The setting in which fisheries are managed is reviewed, with special reference to the discussions at the United Nations Conference on the Law of the Sea. The processes in fishery management are compared with those of management in general, and each component examined in detail. The need for looking at the system as a whole is also stressed, and proposals are made for further action.

Working papers prepared for the meeting are given as Appendices.

An interim report of the Working Party, based largely on the discussions during its First Session (Rome, 6-13 December 1978) has been issued as FAO Fisheries Circular No.718.

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SUMMARY

The fisheries of the world are in a time of fundamental change and tremendous opportunity. This has come about not through any great improvement in the state of fish stocks but through radical changes in the rules governing their exploitation; specifically through the extension of fisheries jurisdiction - usually out to 200 miles - by most of the world's coastal states. Although these changes have been made unilaterally, they match the blueprint for the future legal regime of the oceans taking shape in the third UN Conference on the Law of the Sea and can, for all practical purposes, be considered irreversible.

Their most important effect has been to bring, for the first time, huge quantities of the world's fish stocks within reach of national management. By the end of 1979 no less than 99 percent of the world's commercial fish catches were contained within these new national fishing zones. For the coastal states involved and for the world community this transformation brings an unprecedented but fleeting opportunity to see resources develop on the basis of sound and rational management and so become reliable contributors not only to the prosperity of the owner nations but to the world's food supply.

Unfortunately, with a few notable exceptions, the coastal states have not yet been able to grasp this opportunity. In many cases the chief result of extended jurisdiction has been to turn key fisheries of the world into arenas for domestic and international dispute. In others, crucial management decisions are being postponed and the development of urgently needed programmes delayed. Although there are many reasons for this inertia, the most common and the most fundamental is a lack of generally-accessible fisheries management expertise in developing nations.

The cost of this delay may not be fully realized even by the new owners of the resource - the coastal states themselves. Conceptions of the value of the fish stocks, formed in the time when they were out of reach of management, do not apply today. Precisely because the fish are now the sovereign property of nations it is possible to think about managing them; about matching fishing effort to the condition of the stocks; to move in an orderly way to develop processing capacity and markets based on stable supply; in general to look forward to great and continuing benefits form the resource. The stocks need no longer be precarious assets here today and gone tomorrow. In this sense they are <u>new</u> assets.

Their value is not unconditional. Overfishing and the other social and economic ills of fisheries mismanagement can occur as easily within these new fishing zones as they did on the high seas. All that is needed to achieve that unhappy result is to adopt a strategy based on letting the fisheries take care of themselves; to let fishing effort and processing capacity grow without limit; to let the course of fisheries development follow the same boom-burst curve it has described in the past.

The Working Party believes that there is a finite opportunity - a window in time - in which the world community and the coastal states can work together to place these new national fisheries on a solid groundwork of management. Delay is dangerous. If action is not taken soon - within five years or so - the opportunity to avoid painful mistakes will be lost, and correction in the future will be costly, not only in money but in terms of social dislocation.

The Working Party also deems it important to note that the challenges and opportunities of the new situation apply not just to some countries but to all. The penalties of fisheries mismanagement cannot be compartmentalized and the benefits of good management accrue in one way or another to all. For instance Country "A" has a tangible interest in seeing fish stocks managed well not only in its own waters but in Countries "B" and "C" simply because better management will mean more efficient harvesting of fish.

In this situation the responsibility of the Food and Agriculture Organization is clear. FAO can and should act now to create an environment in which rational management of the fisheries can be instituted and can flourish.

The Working Party believes this will call for the creation of completely new institutions, the modifications of old ones and for the intensification and expansion of work already being done, nationally and internationally. The management rights and responsibilities are clearly those of the sovereign nations who have asserted ownership of these resources. Nevertheless the task is worldwide in scope and too large and complex for any one nation to tackle alone. For this reason and also because success or failure will affect all nations, FAO has a clear responsibility to provide the necessary support.

As noted earlier, the pressing and immediate challenge is to mobilize fisheries management skills in many fields and to create a cadre of expertise that can be deployed for the use of any member nation requesting it.

We must note at this point that although in many respects work of this kind has long been done by the Organization, the wholesale extension of fisheries jurisdiction has so magnified the scale of the challenge that the new task cannot be considered as simply a continuance of the old. There is another difference to consider: given the immense expansion of the amount of the resource that is now manageable and given the new imputed value of the stocks to the owner-nations, the issue is not simply whether management is being practised, but how well it is being practised. To put it more simply, more than ever, the quality and completeness of management is crucial.

The group notes an urgent need for coastal states to take certain specific actions now but also wishes to point out that these cannot usefully be taken in a piecemeal fashion. If they are to justify the investment made in them, they must be made within the framework of a coordinated strategy.

In the framing of this strategy, Step One must be a clear formulation or definition of the management problem. In making this definition, governments involved should note that many of today's fisheries difficulties stem from inadequate and narrow definitions which have come into being because specialists in one field or another have focussed too narrowly on their own areas of concern.

One result has been a common absence from the fishery-management stage of some key members of the cast; the investment banker and economic planner being obvious and important examples. Within the various disciplines that were directly involved and continuously consulted, some specialists have developed narrowly-focussed perceptions of fisheries problems. For instance, the biologist has focussed on fish yield, the economist on cost/price ratios, the sociologists on the contentment of the participants, the politician and the administrator on the need to minimize conflict within constituencies and spheres of influence. Other figures in the fisheries: fishermen, processors, investors and others have made their decisions on the basis of different and sometimes opposing conceptions of benefits and risks.

Even within individual fishery management agencies, narrow perspectives can and have caused conflict and delay. For example, one office may be found waging an all-out campaign to limit fishing effort while across the hall another office conducts a programme to subsidize the building of still more fishing boats. The results of these conflicts manifest themselves in acrimony, counter-productive regulation and a general retardation of the kind of mobilized and sustained effort needed to realize the full benefits of the resource.

Realistically speaking, even the most brilliant and influential fishery manager cannot hope to reconcile every last one of these interests and concerns; nevertheless he needs to take them into account as strategy is developed. Unless this happens it is inevitable that various aspects of the complete problem will be addressed inappropriately - a common example being the earnest search for a technical solution to a problem that is basically political.

The Working Party believes fishery management will benefit from recognition of these potential pitfalls and from a commitment to look at management not as a hodge-podge of separate activities but as a coordinated system involving the following components:

- Setting of objectives
- Definition of boundaries
- Collection of data
- Transformation of data into information
- Formulation of action
- Execution of policies
- Evaluation

The Report deals with each of these components in detail. The Working Party calls particular attention to the following aspects:

- A need for better information and for greater efficiency in the collection of data.
- A need for new analytical techniques with which to approach the broad issues of fishery management.
- A need for greater attention by fishery managers to communication, enforcement and other management functions. In particular, fishery managers need to carry out more evaluations including evaluation of the results of fishery management decisions and "response evaluations" (measuring the impact of crisis control and other unprogrammed diversions on regular work).

More generally the group believes that it is not useful to measure success in individual salients of activity. Evaluations must be made across the whole broad front of fisheries management. If this is not done there will be costly dissipation of resources. For example: the purchase of a sophisticated data processing system is often a necessary and useful step, but realization of its full benefits will depend on having a steady supply of fisheries data for it to process. The setting up of an elaborate management system will pay off only if the regulations on which it is based are effectively enforced.

The Working Party is convinced that above all, improvement in fisheries management hinges on a better use of people. Much of this improvement can come simply through more and better training and through the allotment of sufficient funds to attract and keep the right numbers of experienced and talented people in the fishery management field.

The group also recommends that national governments and FAO both make greater and more focussed use of mass communication techniques to increase public understanding of the value of the fisheries.

The group notes too that extension of jurisdiction have profoundly changed the role of FAO's regional bodies and believes that their direct and indirect management roles under the new regime of the sea are not yet clearly defined or understood. They will still have to deal with special problems; for instance those involving shared stocks, and especially tuna and other highly migratory species. They will also have to serve as meeting places for the discussion of problems and as clearing-houses for information; indeed these services will be more in demand than ever for small countries managing large resources on limited budgets.

With all this in mind the Working Party recommends that FAO reappraise the role of regional bodies in this new environment, paying note not only to their role in the management of shared stocks, of stocks in waters outside national jurisdiction, but also of stocks that are completely within national jurisdiction.

The group has also noted the obvious but important fact that in the absence of any reliable benchmarks for "perfect" fishery management it is going to be very difficult to evaluate performance. Nevertheless evaluation is essential and the Working Party recommends that FAO sponsor a study of methods of evaluating fishery management performance.

The group also considered certain tasks that it is possible to think about tackling immediately and offers the following conclusions and recommendations:

Objectives - National governments should move now to define their fishery management objectives and to identify and resolve any possible conflicts between these objectives.

Boundaries of the Problem - As noted elsewhere, vague or incomplete definition of fishery management problems has caused many difficulties. The Working Party notes that existing literature offers little guidance to those seeking wider definitions of these boundaries. It recommends an FAO study of this subject.

Data - Detailed suggestions regarding ways in which the availability of data could be improved are given as an Appendix to the Working Party's report. The group endorses these suggestions and urges that they be acted upon.

Information - The Working Party is convinced that fishery managers can benefit from a wider and better use of modelling techniques not only to predict events but to understand problems. At present, models are at hand that describe only parts of the entire picture - e.g., models of the behaviour of stocks of single species, but there are no reliable models which deal with biological interactions between different species. This lack is due more to fundamental scientific uncertainty than to any built-in incapacity of modelling systems to deal with the subject. There is also a lack of models that describe the behaviour of management systems as a whole. The fisheries management field particularly needs consideration of multiple-species stocks and multi-species fisheries. Without such consideration, action tends to go forward on the implicit premise that each stock lives in isolation from the others. The Working Party recommends the development of models to help in understanding these problems.

Formulation of Action - The group notes a widespread need for national governments to widen their fisheries management horizons so that they perceive not only the biological readings but economic and other indicators.

Enforcement - Because the enforcement of fisheries jurisdiction is a pivotal and expensive part of management, the Working Party recommends that a study of enforcement methods and costs be undertaken as one of the first steps taken by national governments in setting up management systems.

Evaluation - Too often no evaluation is made of how a management system is performing. Where evaluations are being made they are usually locked in on isolated parts of the management process. The Working Party urges governments to make evaluation of the entire fisheries management system a continuing discipline. It believes that this scrutiny will be most penetrating, and therefore most useful, if it is done from outside the fishery management system. The group also notes that because of the pressure of many different external influences, the most difficult evaluations to make will be those that gauge impact, in other words the evaluations that ask the question "is what we are doing making any difference, and if so what?" It recommends that FAO commission a study of ways to make impact evaluations more precise.

The group further notes that the most important evaluations of fishery management will be made, not by international bodies but by nations.

Fishery managers can also benefit from a more complete knowledge of what is going on in fishery management around the world and an inventory covering this field would be universally useful. FAO has been providing regular information to the Committee on Fisheries on two related areas:

- Review of the state of world fisheries
- Activities of regional fisheries bodies.

These are useful reports and should be continued. The Review of World Fisheries should be widened to cover not just the state of fish stocks but the success of management measures. Both reviews should make a point of reporting on the effectiveness of various management systems, identifying successes and the reasons for success.

Structure and Communication - The Working Party notes an absence of communication between some of the key sectors involved in fisheries management - for instance between investment planning and resource science. It believes that this isolation has come about, not simply because of differences in terminology or other difficulties of dialogue but because these sectors are not in communication at all. One result has been that many decisions that affect the fisheries (for instance decisions on matters of taxation and investment and on resource conservation) are made in separate compartments and sometimes at cross-purposes.

The group urges governments to coordinate the work of these decision-makers. It believes that governments should make room in their organizations for one individual or agency with a complete overview of all the decisions that directly or indirectly affect the fisheries.

The Working Party also notes that unless governments keep a close eye on the effects of investment on fishery management they can expect to encounter the same crises of over-capacity that in the past have caused so much hardship for fishermen, processors and the communities built around them. A watchfulness about investment and a commitment to apply it precisely is also needed on the world stage. Large investments are currently being attracted to the making over, in developing nations, of artisanal fisheries into modern and highly-mechanized operations.

Training - As stated earlier in this report, a better supply of trained people is the sine qua non of improvement in world fishery management. The group urges FAO to move rapidly to establish an International Institute of Fishery Management to train professional fishery management people and to sensitize national decision-makers to the importance and the needs of the resource.

The Institute would offer training at different levels, and for different periods. Top officials would be offered short three or four-day seminars open to very senior people from all parts of the world; longer courses of one to four weeks would be offered at the regional level for middle-level fishery managers, while a limited number of two-year fellowships will be available to selected younger people. The Institute will also support special seminars focussing on the needs of individual regions, or particular types of fishery. A detailed proposal for such an Institute is included as an Appendix to the Report.

The Working Party stresses that the need for this Institute is urgent. It notes the presence of a handful of fishery management training programmes in different parts of the world and the fact that the Institute would work closely with these institutions, but it points out that these programmes are not geared in scale or in scope to meet the world-wide need created by the extension of fisheries jurisdictions.

Unless these projected increases in fishing capacity are fitted into a realistic plan for management of the stocks, these fisheries will inevitably suffer the penalties of over-capacity that have marked unplanned development in the past.

Consequently the Working Party urges FAO to take measures to create the kind of environment in which decisions about fisheries investment can be made on the basis of a full supply of information about the other factors in the management equation. This could be done in the setting of senior-level seminars bringing together investment bankers, resource specialists, fishery managers and other key influential people now working in dangerous isolation. FAO should also be ready to give nations that request it, the advice they need to make sound decisions about investment in their fisheries.

The Working Party believes that a World Conference on Fishery Management would serve two distinct and useful purposes. It would serve as a forum for technical discussion and the sharing of experience and it would also be an excellent device with which to focus influential world attention on the fisheries. Both of those ends would be served not only during the Conference but in the course of its preparation which would be marked by preparatory meetings on specific topics. The Working Party notes that FAO is considering such a meeting and gives its full support to this project.

To sum up: The Working Party believes that the opportunities presented by the new situation of the world fisheries require immediate action. Given such a response - one based on an accurate diagnosis of past problems and a complete perception of present management needs - great benefits can be realized, not only by coastal states but by all nations. It stresses that although success depends on an adequate deployment of money and other resources, it will also hinge on an intelligent and precise ordering of priorities and objectives - and above all on the ability of the world community to do what needs to be done in time.

1. Introduction

The fisheries of the world are not being managed well. Conflicts of interest between countries and within countries (e.g., between traditional and industrial fishermen) are common. Some stocks, notably of whales and North Atlantic herring, have collapsed, and the important fisheries that they used to support have virtually disappeared. More generally, failure to control the amount of fishing has led to excessive costs, falling catch rates, and the individual fisherman getting, at best, a marginal return for his efforts.

Changes in the legal regime of the sea have created opportunities to modify this situation and for countries to manage their fisheries. In general, though, it has proved difficult for countries to grasp these opportunities, and to realise the benefits that could come from better management and a more rational utilization of the fishery resources off their coasts.

The main reason for this is that fishery management has been thought about in too narrow a sense - often as no more than the imposition of restrictive controls determined by purely biological considerations only after a fishery that has got into severe difficulties. To be successful, fishery management should comprise all decisions that can affect a fishery, from the early decisions to invest in a few boats onwards, and should take account of wide economic and social considerations.

History of the Working Party

The present Working Party was established by the Advisory Committee on Marine Resources Research at its Ninth Session (Rome, 1978). It has held two meetings (Rome, December, 1978, and Hong Kong, December 1979). After the first meeting it issued an interim report (FIR/C718), which contains a number of studies prepared by members of the Working Party for consideration at that meeting. This report contains the essence of the material in the earlier document, but the latter should be consulted for detailed examination of some subjects (e.g., shared stocks).

Early in its deliberations the Working Party became aware that, if it were to do justice to the urgent problems of fishery management, it would have to take a wide perspective, and go beyond its original terms of reference as listed in its Interim Report. This procedure was agreed by the Chairman of ACMRR, and by FAO.

This report thus attempts to view fishery management in a wide context, i.e., as management of all activities concerned with fishing, rather than as management of the resource. It attempts to provide a framework for countries setting out to manage their fisheries, particularly in the new situation created by the establishment of exclusive economic zones.

Any fishery management programme should produce benefits, e.g., greater catches, reduced costs, or a more socially desirable balance of income, but will incur costs, e.g., in providing the necessary research results, or administrative framework. These benefits and costs are largely determined by the quality of a multitude of decisions made by many different people (fishermen, investors, entrepreneurs, administrators, etc.) in many different organizations. The task of management is to ensure that the proper objectives are set, and that these decisions are coordinated and lead in a cost-effective manner to the desired objective.

The framework described here should help countries to do this. It is based on the concepts that (1) fishery management is a decision-making process which is structurally the same as any other management process, and (2) that successful fishery management will need to operate as a total management system.

The report falls in four main parts. First, a review is given of the nature of the problems now facing fishery managers, especially following the changes in the legal regime of the sea (Section 2). This is followed by a brief description of fishery management as a system, which draws attention to the similarities and differences compared with any other management or decision-making system (Section 3).

Any management system consists of a logical sequence of processes, from the definition of objectives to the execution of action, and the review of what has been done. The problems involved at each of these steps is examined individually (Section 4). The next section of the report examines the need to look at the management system as a whole (Section 5). At the end of the report itself there is a short section bringing together the general conclusions of the Working Party, and its suggestions for actions that need to be taken by nations individually, or by FAO, to improve management.

In addition, a number of studies prepared between the two sessions of the Working Party, which give more detailed information on a number of specific topics, are included as appendices to this report. Particular mention should be made here of the description of a possible International Institute for Fishery Management (Appendix 2).

2. The Environment of Fishery Management

Decisions about fishery management, like any other decisions, are determined by the environment in which they are made. This section of the report examines some of the factors that influence these choices.

One highly significant factor is the status of fish stocks as common property, open to exploitation by all comers. Another is the international legal framework in which the fisheries are managed, which is changing rapidly and profoundly as a result of the Third UN Conference on the Law of the Sea. As a result of these alterations and the new opportunities they bring, the fisheries are taking on a new importance in the eyes of many nations, and the resulting changes in attitudes are making it possible to approach many old problems in new ways - including problems that stem from uncontrolled access to a common property.

Along with this general widening of options for fishery managers come some new problems, notably that of distributing the benefits of these newly-acquired resources.

2.1 The common property status of fishery resources

Decisions taken by fishermen, fishing companies or investors which are perfectly sensible in terms of the individual, can have results that are far from desirable in terms of society or of the over-all fishery. Because fish stocks are common property, the activities of any one fisherman affects the catches of all others exploiting the same stock. One result of this is that the catches taken by a new boat added to a fishery are not a good measure of the benefits, to the fishery as a whole, produced by that additional boat. Unless the stocks are lightly fished, the net addition to the total catch will be less than the catch by the additional boat, the difference being the reduction in the catch by the existing boats. This is sometimes hard to observe in the short run, especially for small increments in fleet size, and it is often masked by temporary changes in stock abundance, but it is nonetheless an accurate depiction of the results of fleet expansion. The individual owner will, in considering the personal profitability of building a boat, be looking at the gross catch of that vessel, and will therefore add to the fleet long after the interests of society, as judged by the small net addition to total catch (i.e., the gross catch, less the reduction in catches by existing vessels) compared with the addition to total costs would suggest that the fishing fleet was large enough. In the extreme, this situation can lead to severe overfishing, and a fall in total catch. It is this difference between the interests of the individual ("will an additional vessel make a profit") and of society as a whole ("will an additional vessel result in an increase in the value of total catch that is greater than the cost of the vessel") that requires the intervention of the fishery manager.

The role of the manager is to control the development of the fishery in such a way that society receives high net benefits. Precisely what should be included in the category of net benefits depends upon the specific objectives of management (see below) but normally they will include such things as the value of catch to consumers less the cost of harvestings, and the distribution of the rewards from harvesting, as well as others. It is important to realise, of course, that management involves costs, including those of research, implementation, and, where necessary, enforcement.

The controls that the manager uses should not consist only of the restrictions usually thought of as the tools of fishery management. Many stocks are still under-exploited, and the fisheries on them could be developed. In other fisheries the fishermen are using old, primitive or inefficient vessels or gear. In many instances, development can, and will be done by the business community without any urging or help from government. In others the fishery does not grow because the fish cannot be caught at a cost below that at which they can be sold. Development of these fisheries may require government intervention in improving harbour or marketing facilities, in technological research into improved methods of catching or processing the fish, or through financial or fiscal means. However, this

intervention, which is an important role of the fishery manager, should always be planned with the ultimate need in mind of controlling development to match the productivity of the resource. Modernization, to take advantage of new technologies, and replacement of old vessels, should be entirely compatible with programmes to prevent over-expansion. It is however vitally important to make a clear distinction between replacement and expansion.

The problem of over-expansion has by no means been confined to free-enterprise economies, and the more developed countries. There has been an over-expansion of the fleets of centrally-planned economies as well. They helped to cause the reduction in catch-per-unit-effort in high seas fisheries that occurred before the change in jurisdiction, and have suffered some of the losses that resulted.

The effects of unlimited expansion of exploitation in both national and international fishery resources have a well established basis in bio-economic theory and have occurred repeatedly. Exploitation expands to a level where the potential economic benefits to the fishing sector are dissipated and if government financial support is provided, fishing will continue until net economic benefits are negative. Typically, exploitation will then exceed the level needed to achieve the MSY. In some cases the recruitment will fall, leading to a substantial fall in total catch. In most cases, the annual catch will be more variable. This adds short-term economic instability to an average long-term level of already low economic productivity.

Resolution of the open-access problem has become more urgent because of increased fishing pressure on a world-wide scale. The growing demand for fish, through increased population, and higher personal incomes in many countries, has raised the world fishing intensity to a level where most of the more valuable stocks are becoming heavily exploited. This is true whether the stocks are off developed or developing countries. The geographical spread of heavy fishing pressure to most of the productive fishing areas of the world, from the Bering Sea to the Gulf of Thailand and South Georgia, has been matched by the spread of species being exploited. The result has been that while the problems of mis-management have increased (witness the collapse of the many herring and other stocks), so also have the potential economic and other benefits from good management increased.

Prior to extension of national jurisdiction the only methods for limiting access, and thus preventing too great an expansion in the amount of fishing, were non-discriminatory controls such as closed seasons. These were often almost as effective in dissipating economic benefits as free competition, even when they were effective in maintaining the biological productivity. Extension of jurisdiction gives national governments greater opportunities to control access. However, until this opportunity is exercised in one way or another, access will still remain open for any national fishermen, and the process of dissipation of potential benefits will continue.

As in the case for any real asset, the control of access and the rights to fishery resources can exist in a wide variety of forms and degrees, ranging from "sole ownership" to something little different from a continuation of open access. The important differences are the degree to which benefits are realised, and the sector of the community that receives them.

For example, the entry into a fishery may be controlled by reducing the incentive through the imposition of taxes or royalties. In such cases the benefits will accrue to the state as direct financial return, and the basic ownership rests with the state. Alternatively, access rights may be granted to a specific group of fishermen, for example, those participating in the fishery on a certain date. If these rights are granted in perpetuity and free of charge (or sold for a lump-sum initial payment), then ownership of the fishery resource is effectively allocated to the fishermen. However, unless access rights are further allocated to individual fishermen (or fishing companies), competition for the available catch will still lead to the dissipation of economic benefits. This

process will generally be manifested through a progressive increase in the size, horsepower, and capacity of fishing vessels, and through a correspondingly brief but intense season of fishing activity. Secondary effects such as reduction of product quality, "boom-and-bust" seasonal periods for processing plants, not to mention direct conflicts between fishermen, may also be evident.

Experience with the few fisheries in which access has been restricted, but rights not further subdivided, has confirmed the theoretical expectation that fishing capacity will expand well beyond a desirable level. If the control is on, say, the number of fishermen or vessels, without further restrictions on the size and horsepower of vessel, the type of equipment, etc., there will be pressure among individual fishermen to expand effort in any way they can so as to increase their own profits. To the extent that there is the ability to substitute non-restricted for restricted inputs, this pressure will result in wasteful expansion of the fleet. Therefore, to be effective, such restrictions may have to be very precise resulting in interference with the incentive for desirable innovations.

Where the ability to substitute inputs is limited due to the nature of the fishing technology involved, a general access restriction programme (such as licensing) can go a long way towards achieving a cost effective reduction in fleet capacity. It is also true that due to institutional constraints, this may be the only type of access control that can be adopted. Although some economic waste may result, if there is an improvement over the open-access situation, such controls can be justified.

Even though there may be instances where a general access limitation programme may be appropriate, there is significant agreement among fisheries economists (see Appendices 1 and 3 and the papers cited therein) that the most appropriate methods for generating substantial economic benefits from fishery resources consists of a scheme of allocated transferrable fishermen - or vessel-quotas. (See Clark, 1979 for a theoretical analysis of this and other regulatory techniques). This system effectively counteracts the competitive difficulties of the common-property fishery by allocating to individual fishermen specific quantitative rights. The practical implementation of an allocated quota scheme would involve a number of serious technical problems, including: (a) methods of handling variations in stock abundance, (b) multi-purpose fleet behaviour and multi-species catches, (c) problems of enforcement. Doubtless, in some cases these problems would prove so severe that an allocated quota system would not prove feasible. In such cases the economic inefficiency of the competitive fishery or of the next best regulatory regime would be accepted as unavoidable. But for important, lucrative fisheries such an allocated quota system could prove highly effective, particularly in cases where the catch is landed at a small number of easily monitored outlets.

Any system of rights allocations carries distributional implications. When rights are allocated to a restricted group of fishermen, those fishermen in effect are the recipients of a valuable gift. If the state, or its citizens, object to the granting of such valuable property rights to selected individuals, then there are two choices. First, the state can retain the rights, and either establish a nationalized fishery (it would be sufficient to nationalize the purchasing sector), or it can impose taxes or royalties, as noted previously . Alternatively, the state can sell or auction quotas to individual fishermen or companies. In fact the state can adopt an intermediate position, by granting quotas to specific individuals and also charging fees (taxes, royalties) which are less than the market value of those rights.

Finally, there may be some cases of localized inshore fisheries (say within three miles of the coast) where devolution of ownership to local authorities (e.g., villages or groups of villages) may prove effective. The small number of fishermen involved in any one particular region may be able, through some system of social pressure, to control the competitive incentive and achieve a well-managed fishery. Examples exist in Japan, where this method has been effective in protecting small-scale coastal fisheries from the harmful impact of industrial fishing.

2.2 Changes in the legal regime of the sea

A most obvious change that is now affecting fisheries and fishery management is the new regime of the oceans arising in part from the U.N. Conference on the Law of the Sea. At this point the Conference has produced an informal negotiating text of a possible new Convention, but it is likely that it will be some time before such a new Convention is signed, ratified and comes into effect. However, there have been few changes in the fishery articles during recent sessions, and the form of the new regime, insofar as it affects fisheries, appears clear. At least it is fair to say that several important notions appear very likely to be included in any ratified treaty. These notions are: (1) a two hundred mile exclusive economic zone; (2) shared stocks; (3) specific requirements of management. Each will have its effect on the potential for and constraints on fishery management.

2.2.1 Exclusive economic zones

Under the terms of the draft Convention coastal states can establish an exclusive economic zone extending 200 miles from their coasts or baselines. In these zones, which many states have already established, coastal states will have control over fisheries, and vessels from other states can only fish subject to conditions set by the coastal state.

This extension of jurisdiction gives greater opportunities to tackle the open-access or common-property problem, discussed in the previous section. Long-range fleets no longer have free and unlimited access to important stocks, management is increasingly compartmentalized, and management measures can be implemented without the need for reaching international consensus on what should be done. The greater opportunity to impose measures that reduce the cost of fishing (principally by reducing effort) should potentially lead to increases, and quite possibly, very substantial increases, in the net value of the fishery (value of the catch less the costs of capture). There will also be an increase in the value of the fish stock as perceived by the coastal state. While the fish were on the high seas and could be caught by anyone, they were often of little concern to the general public, but once jurisdiction is extended, the fish become considered as 'our hake' or 'our sardines', and thereby of much greater concern, regardless of any change in the immediately realisable economic value.

The changes do not necessarily bring immediate concrete benefits, even to the coastal state. The economic and practical obstacles to fishery development are unchanged. If a country has found it difficult to develop a national fishery in the past, it will find the same difficulties after establishing an EEZ, and in some cases the problems may be worse.

While the establishment of EEZs gives the coastal state authority within its economic zone, there are natural limits to the independence of this authority. The boundaries of national jurisdiction will seldom coincide with the boundaries between fisheries or fishing grounds. Still less do they, in general, coincide with boundaries between fish stocks. The movements of individual fish, whether as part of large-scale directed migrations, or as more irregular dispersion, will take many of them across the boundaries between adjacent EEZs, or between the EEZ and the high seas so that not all, and possibly only a minority of stocks, are of concern to a single coastal country.

2.2.2 Shared stocks

Prior to the establishment of EEZs the problem of covering the complete biological unit was handled through various international fishery organizations, which generally had a geographical scope which included the total range of the stocks concerned. Some organizations were responsible for a defined area containing localized resources, and others were responsible for particular groups of species (tunas, whales) with a more extensive range. It was implicit that the management body should have authority over all activities within the fishery system that influenced the abundance and productivity of the

resource. The system was defective in that there was no obligation upon participants in the fishery to become members of the management body, and conflicts of interest both within and outside the body influenced the efficiency of allocation of any rights to the fishery. The adoption of EEZ has vested authority over resources in more restricted areas to the appropriate states and so modified the institutional system within which allocation problems may be solved. But at the same time the restriction in area has led to the identification of a greatly increased number of "shared" stocks, that is, stocks whose areas of distribution cover the EEZs of several countries, and whose management requires cooperation between these countries. The pre-UNCLOS conflicts of interest within a management agency have simply been externalized as conflicts between management agencies responsible for smaller areas.

In discussing the problems of "shared stocks" it must be recognized that there are a number of different circumstances under which two or more countries may be said to share the same "stock". The concept of 'stock' itself describes a variety of situations. In the simplest the whole population of a given species of fish consists of a number of clearly separable groups of fish, each of which spawns in well-defined and fairly restricted areas. Each of these groups is a stock, and by following the migration of each group it is easy to tell which are shared by which countries. Other species may be distributed more or less continuously along the coasts of adjacent countries with no identifiable separations between different groups, or distinguishable spawning grounds. Movements of individual fish may be sufficient to ensure mixing between adjacent areas and across national boundaries, but slow enough for there to be only limited interaction between fish in more widely separated areas. For such species it is difficult to define a stock, and though the adjacent countries do share the same resource, the nature of the sharing is very different from that of sharing a single migratory stock. Management of any group of fish that crosses national boundaries therefore requires knowledge of the pattern of movement of the fish, and of the locations of spawning grounds, nursery areas, etc.

The management of shared stocks under the new regime presents a set of problems that are additional to those of a stock that lies wholly within a single national jurisdiction and different from those of stocks exploited by multi-national fisheries under the old regime. For the latter, where vessels from different countries could fish on the same grounds, often very close together, the long-term effects of action taken by any one country were experienced equally by all countries. A country could experience a net benefit from unilateral action, e.g., to reduce effort, or increase mesh size, only if it took a preponderant share of the total catch. Under coastal state jurisdiction different countries sharing the same stock will harvest that stock in different areas, and often at different seasons, and take different ages, sizes or conditions of fish. The impact of action by one country will not be felt equally by all countries. If the rate of mixing across the boundary is slow the impacts on other fisheries may be so small that each country can effectively take independent action to manage the fisheries within its national EEZ, without having to worry about the relatively minor impact on other countries, or about the impacts on its fishery of actions taken by others.

At the other extreme the benefits of management action taken by one country can be felt most by some other country. For example, if a migratory species spends its early life in one EEZ and then migrates to another EEZ where it is harvested as adult fish, the benefits of actions to reduce the fishing mortality on juveniles in the first area will be mainly felt in the second. Who receives the benefits is obviously important because the country instituting management will, in the absence of specific agreement, bear all costs, and it is unlikely to do so unless the benefits it receives are greater than its costs.

Some of the technical aspects of management of shared stocks were discussed in the Working Party's Interim Report, and the details need not be repeated here. Successful management will require the full exchange of data; joint interpretation of the state of the stocks; agreement on the desired pattern of exploitation, taking account of the migrations and other characteristics of the resource, as well as the various national objectives; agreement on the share of the total benefits to be taken by each country

(normally involving the division of the total catch in agreed proportions), and arrangements for mutual inspection so that each party is assured that the other is carrying out the terms of the agreement.

2.2.3 Requirements for management

Besides codifying the establishment of Exclusive Economic Zones, the U.N. Conference on the Law of the Sea draft texts contain other fishery management provisions. Some of these are very general and do not significantly change management problems; they point out the need for conservation and management, or call for cooperation between states interested in the same stock of fish. Other provisions concern only specific groups of species - anadromous or catadromous species, or sedentary species, and present special management problems from which no general conclusions can be drawn. However, there are a number of provisions that could significantly affect fishery management. Our concern is not with a critical review of detailed texts, but with a more general examination of the possible implications of how the management system might be affected.

The principal points concern resources management within national EEZs, and the substantive aspects are essentially as follows:

(i) Each coastal stage should determine the allowable catch in its EEZ.

(ii) Management measures should be aimed at providing the maximum sustainable yield (MSY) as modified by a complexity of biological and socio-economic factors.

(iii) There is a 'surplus', equal to the difference between the allowable catch, and the national capacity to catch fish.

(iv) Other states should be allowed access to this surplus, subject to any reasonable condition set by the coastal state.

The above points can affect the objective of management chosen by a particular country. Apart from general statements about the need for conservation and management, and the optimum utilisation of the living resources, which allow the pursuit of any reasonable objective (i.e., other than the pursuit of immediate short-term gains regardless of the long-term consequences to the resource), the only explicit reference to a well-defined objective is to the maximum sustainable yield. The MSY objective as specified by the proposed treaty is qualified by so many complex environmental and economic factors that it is simply a reference point for describing the management objective in any given situation. In this respect therefore the new regime will not necessarily alter how countries should set their objectives, particularly since MSY as an objective of management has been criticized by many authors on biological and economic grounds.

The points noted above, especially the first, concern the methods of measuring and controlling the amount of fishing to achieve a desired level of exploitation. The ultimate objective will usually be conceived in terms of the fishing mortality (i.e., the proportion of the stock that is caught per unit time), but it is impossible to directly control or measure fishing mortality. Two indirect measures are available - either catch, or the nominal fishing effort (the number of boats, the time they spend fishing, etc.). There has been considerable discussion on the advantages and disadvantages of these measures. In brief it can be said that neither is perfect, and neither can be preferred to the other in all situations. Control of mortality by controlling catch, e.g., by quotas, has been found preferable in most international fishery commissions, mainly because it provides a standard that can be applied to any vessel - a ton of cod is a ton of cod, whoever catches it, while it is not easy to compare a day's fishing by a large factory trawler with a day's fishing by a small inshore boat. However, control by catch does have disadvantages. Most stocks fluctuate in abundance, and the catch has to be adjusted from year to year in order to maintain the rate of exploitation at the desired level. If the fish are short-lived, or the fluctuations are large, obtaining the data necessary to make the necessary

and timely adjustments to the allowable catch for each year may require a large and difficult research programme. Catch quotas are usually set as a means of limiting rates of fishing mortality. Fishing mortality is influenced by the level of fishing effort. Limitation of fishing effort, e.g., on the number or size of vessels, is a valuable complement to catch quota regulation and may be a more effective means of preventing excessive fishing. This has not been recognized in the Law of the Sea text.

The draft LOS text mentions the problem of determining fishing mortality twice; once a direct statement that coastal states shall determine the allowable catch, and second, a listing of conditions that coastal states could impose on other fishermen in their EEZ, on which both limitation of catch and control of the numbers and types of vessel are included, with no suggestion of one method being preferred to the other. These existing drafts on this matter could influence the way in which countries manage their fisheries to the extent to which the requirement to determine catches is followed. If interpreted in the most narrow fashion, with specific figures for each stock - which would have to be varied each year - this could involve a country in costly research, and a possibly inefficient management system. A broader interpretation, that by setting other controls, e.g., on number of vessels, the coastal state would in fact determine, if only indirectly, how much is caught, would allow a more flexible, and in many cases more effective, management system. It may also be noted here that a narrow interpretation can lead to severe difficulties in the case of shared stocks. If two countries set allowable catches independently in respect of the exploitation of the same stock in each of their EEZs, and the sum of these catches exceeds the sustainable yield from the stock, it is clear that the stock will decline. This situation could not go on for long without disaster.

The third point in the LOS text deserving comment here is the concept of surplus. The clear intention is that if resources exist in the EEZ of one country that are not being fully utilized by that country, the coastal state must allow foreign vessels to harvest the resource, under suitable conditions. If the coastal state does not fish for the resource in question, and its exploitation can be carried on without interference with other fisheries of the coastal state (e.g., through biological or technological interdependence) there is little problem unless the domestic country plans to enter the fishery later. Foreign fishing will reduce stock abundance, and hence potential catch rates, and in this way make it less easy for coastal states to enter the fishery. Against this, the information on the stocks and on the best fishing grounds and seasons could make entry easier.

There are, however, greater problems if the coastal state does already fish for the resource in question. The implication of the draft text is that there is a surplus, equal to the difference between the allowable catch (however this may be determined) and the catches by the coastal state, and that this surplus can be taken without affecting the coastal state's fishery. The latter can only happen under exceptional circumstances; normally any additional fishing will reduce the stock abundance, and hence cause the catches by the existing fishermen to fall or the costs they incur to take a given catch to rise. There could therefore be a tendency for coastal states to define the allowable catch as that catch which will maintain the stocks at a sufficiently high level as to allow the fishermen of the coastal state to operate successfully. This, then, by a happy coincidence, may be equal to expected coastal state catches, leaving no surplus. In other words, while there may be a 'surplus' in the sense that the total catch may be increased, on a sustained basis, above the level of the catches of the coastal state, harvesting this 'surplus' cannot, in general, be taken without some costs to the existing local fishery.

2.3 General problems of fishery management

Apart from the problems of open access, and changes in the legal regime of the sea, which are specific to fisheries, there are several problems that are common to most management situations, but are very marked in fishery management. These include (1) the need to define the boundaries of the management system correctly, and to have effective communications between different interests; (2) the complexity, variability and uncertainty

in many elements; and (3) the constraints imposed by shortage of finance, manpower, etc., to implement management.

2.3.1 Definition of boundaries

Historically fishery management has been concerned as a biological problem, dealing with the conservation of fish stocks and improving the physical yields harvested from them. It has often been felt that it is sufficient to ensure that the stocks are maintained in a condition in which high catches can be taken, without much concern of what benefits are gained from the catches. This attitude is now changing, and it is recognized that fisheries is an economic activity involving a broad spectrum of individuals and interests. Catching or not catching fish affects not only fishermen, but processors and consumers as well. The success of management, in terms of the full and rational utilization of the resource depends on many decisions, taken by investors, tax authorities and others in addition to those setting management controls (e.g., catch quotas).

The problem of identifying the correct boundaries to the management problem, and of ensuring that no important interest and influence is omitted, is discussed further in Section 4.2. What should be stressed here is that although the wider view of management is becoming accepted, the narrow, biological view is still common. This makes taking the larger view difficult and a matter that will often require special attention. In particular the communications between different interest are often poor. Even within a single government, that part charged with economic development may be encouraging increases in fishing effort through low-interest loans or tax relief for boat-building, or exemption of custom dues for engines or fuel, at a time when another part, charged with conservation of fish resources, is attempting to reduce effort.

The previous concentration on the biological aspects of management has also led to confusion between the roles of the decision-maker - usually a senior administrator - and his technical advisors. When the only objective was biological - e.g., attaining the maximum sustained yield - then the administrator had little more to do than to endorse, or reject, the recommendations made by the scientists. With objectives that are wider, and less easily definable in quantitative terms, the role of the decision-maker is more complex and important. It requires a better communication between administrator and technical experts than is presently the case.

Actually, the problem of developing coordinated action between technicians and decision-makers has deeper roots than would be reflected by a simple communication problem. The most fundamental cause of the problem is that technicians and administrators often have different objectives. The technicians seek first to define biological or economic objectives, commonly in terms of maximizing one or other quantity, and then to find ways for attaining these. Usually, the ways to attain these maxima involves social costs. Put more simply, they involve changing the ways in which people have traditionally pursued their professions or their consumption patterns. The decision-maker, however, has incentives, and thus objectives, that are often very different and frequently not at all consonant with the technical objectives. The decision-makers primary objective tends to centre upon minimizing the political contentiousness of issues. This is a good motive, but the method of its attainment can be damaging. If on one hand political contentiousness is reduced by resolving conflict, then it is likely that society can attain at least some of the technical benefits. If on the other hand political contentiousness is dealt with by avoiding accountability, and even the discussion of difficult issues, and avoiding the taking of decisions, then society will benefit little and may even be harmed.

As management systems develop it will be evident that it is important that the technicians be insulated from decision-making objectives as well as to make sure that technicians address the technical issues of concern to decision-makers. At the same time it is necessary - and this cannot be over-emphasized - for decision-makers to strive to minimize conflict through the attainment of technical benefits rather than through letting the problem sift, unfocussed, like grains of sand through a sieve.

2.3.2 The complexities of the system

Fishery management is often discussed and prescriptions for better fishery management put forward on the implicit assumption that fisheries take place in a simple uniform setting in which the only disturbing factors are the changes brought about by the fishery being discussed. This is very far from being the case. Fish abundance fluctuates from year to year. Over longer periods stocks rise or decline or one species is partly or wholly replaced by another for reasons that are quite independent of fishing and outside the control of the fishery manager. The recent rise in fuel prices has completely altered the economics of many fisheries, and hence changed their needs for management. Different elements in the fishery system interact in ways that are not taken into account in the simple models. In all areas there are real but generally unknown interactions between different species. For example in the North Sea it is possible that the success of the fisheries for demersal species such as plaice or cod may be influenced by events in the pelagic stocks such as mackerel and herring, and the success or otherwise in managing these species - even though it is far from clear exactly what these interactions are. The failure to maintain the eastern Atlantic herring stocks also had wider repercussions; the shortage of herring in Europe has greatly increased the price of herring from the western Atlantic, and hence changed the setting in which other stocks of herring are managed. Objectives too can change. The political imperative of maintaining employment in fisheries in an isolated community can disappear if oil drilling, for example, provides a much more attractive alternative employment.

The problems of taking account of the variability and interactions of many elements in managing fisheries are increased by the fact that it is not at present possible to describe or predict them with any precision. The uncertainty of the effect of changes in herring or mackerel abundance on the stocks of cod or plaice (and in particular on the recruitment to these stocks) is typical of many of the inter-specific interactions that are suspected of being important. Even within a species there is considerable uncertainty about the effect of changes in adult stock size on subsequent recruitment. The same is true of most other elements. For instance, it would be a bold man who claims to forecast the price of fuel in five or ten years' time - other than suspecting that it will be high - but the price of fuel is very important in setting fishery policy.

These complexities affect most stages of the management process, but more particularly the stages of interpretation and information and of decision-making, and at the link between them. The impact is likely to be greatest in the form of the advice offered by biologists on the state of the stocks, and by other specialists. It has come to be expected by both the specialist adviser, and by those receiving the advice, that the information can be presented in quite definite terms - for example "the mesh size required to give the biggest catch is so many mm", or "the catch quota required to rebuild the stock is an exact number of tons". Not only do the complexities noted above make these statements more complex - "a specified mesh size will maximize the yield of species A, but will increase the predation of A on species B and C" - but they become less precise and definite - "a reduction in quota from X tons to Y tons will increase theprobability of a good recruitment within the next five years". The decision-making process therefore cannot be merely an endorsement of proposals arising as a result of a more or less mechanical application of certain procedures to the basic biological information, but must involve a balance between probabilities. The interesting point is that this is quite a typical situation in decision-making, and the recent situation in fishery management by which those actually responsible for managing have tended to delegate their responsibilities to their scientific advisers needs to be rectified.

The uncertainties also affect the final stage of evaluation. It is easy to check whether a reduced herring quota has resulted in a reduction in catch, but it is less easy to check whether the aim of increasing recruitment is achieved. Recruitment may turn out to be poor - but might have been even worse if catches had not been reduced. Equally, if a good year-class occurs, there can be no certainty that an equally good one might not

have happened if no action had been taken.

2.3.3 Constraints

Authorities concerned with fisheries management usually have to compete with other authorities with other interests for limited resources of trained manpower, government finance, etc. These constraints may be less severe in the major fisheries of developed countries, where the value of the fishery is large, and the governments have, comparatively speaking, ample resources. In contrast many individual fisheries in developing countries are small, and the governments have limited resources.

However, even in the best situation resources are not unlimited, and are inevitably less than that required to provide what everyone would consider as an ideal management system. It is therefore important that the resources that are available are deployed in an efficient manner. In most of the management systems of which the Working Party is familiar the resources seem to be deployed in a less than optimum manner, and the Working Party suspects that this is true for management systems nearly everywhere. In particular the less attractive elements, such as collection of the right kinds of basic data, or evaluation of the performance of the system, are usually neglected.

Efficient deployment of resources is ever more vital in developing countries. Here it must be stressed that shortage of resources does not mean that the nature of the management process is changed. It is still essential to collect data, interpret it, reach decisions, implement them, and evaluate the result, but each stage must be executed in a simple and cost effective way, using the resources at hand.

At the same time it has to be recognized that there must be a stage at which resources are so limited that no effective action can be taken. This can well be the situation in some developing countries, especially in respect of a shortage or absence of personnel with the necessary training and experience. In these situations the first step will have to be training. Much attention has been given to the training in individual specialities relevant to management (collection of statistics, stock assessment, etc.), including the preparation of manuals. Much less has been given to training in fishery management as a unified subject.

3. Management

As suggested in Section 2, the successful management of a fishery is a complex undertaking involving the pursuit of varied and sometimes conflicting objectives - political, social, economic and otherwise. Success depends, moreover, on an accurate definition of the limits of the resource and, because the reaction of fish to exploitation and management is difficult to predict with precision, this is not an easy condition to fulfil.

Despite these complications, fishery management, structurally, is the same as any other management. That is to say the manager addresses a given objective and in the course of working towards it must do the following things:

- gather information about the objectives
- make decisions
- evaluate performance

On the basis of this experience the manager then evaluates performance, modifies objectives and makes any necessary changes in processes - including the evaluation process.

3.1 The fishery management process

In general, the management process consists of the following activities (see Fig.1).

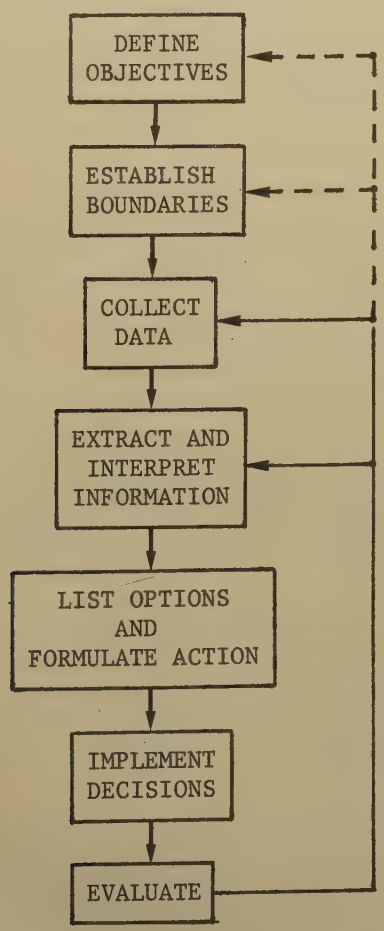

FIG. 1. A schematic representation of the components of a fishery management system.

First, general objectives and policies are established, and the boundaries of the problem are established. Next, data are collected, analyzed, and presented to management in the form of usable information. On the basis of this information, options are examined, and then decisions are taken and implemented. Finally, the results of the decisions are observed and evaluated with reference to the original objective. If the performance is unsatisfactory, the entire process may be repeated in order to improve performance. In some cases the original objectives may prove to have been unrealistic, and may be modified accordingly.

The evaluation will usually show that it is necessary to repeat the process from the point of collecting data or of interpretation, as indicated by the full lines on the right hand side of the figure, but in some circumstances it may be necessary to re-examine and re-define the objectives, as indicated by the broken lines.

In the case of fishery management the definition of objectives was, in the past, a straightforward, if not simple, task. For instance, one objective may have been to equilibrate fish supply and demand through the free play of market forces. A comparably simple objective has been to catch the maximum sustainable yield (MSY).

Experience and confrontation with the facts of life have forced an abandonment of this simple biological or economic logic and today fishery managers, and the societies in which they operate, must consider more numerous and less simply defined objectives. For instance, objectives might include several of the following: maximize yield while minimizing the danger of a fishery collapse; control predatory species; reduce by-catches (e.g., of porpoise taken with tuna); limit catches of species which are the food source of other species; maximize total economic yield from a multispecies fishery; prevent over-expansion of fishing and processing capacity; maximize foreign exchange; provide employment opportunities; stabilize fish stocks and/or fishermen's incomes; and minimize political conflicts.

Being clear about objectives, about whose interests are served or neglected by their pursuit and about the conflicts and contradictions that may flow from them, is a crucial prerequisite for the management of a fishery. Given an objective defined in general terms, it is then necessary to identify the measures that can be used to determine the success in achieving that objective. If, for instance, the over-riding objective is to catch fish to feed a starving population (a plausible circumstance for many countries) then the relevant measure would be something like "rate of decline and absolute number of starvations, per unit time, for a nation as a whole".

The next stage is to set the boundaries to the units being managed. This involves problems in many disciplines. The most obvious are the biological ones - how far do the fish move, which fisheries exploit the same stock, what other stocks will be affected because they feed on, or compete with the stock of primary interest, etc. - but there are many others. For example, controls on the amount of fishing have implications on the industries supplying the fishery - boat-builders, etc. - as well as on the marketing and distribution of any type of fish that supplies the same market. If the manager attempted to take account of all the indirect effects of his actions, he would be setting himself an impossible task. On the other hand, if he does not take account of important consequences, he will fail to achieve his proper objectives. Therefore he must at an early stage determine the boundaries of the units with which he will be concerned. This may require study, e.g., to determine the migrations of the fish.

The next stage is to collect the data he needs. Even for "simple" stock assessment, complex questions arise. What specific data to collect? How much of the total management budget to spend on data collection? Are the sampling theoretic approaches used in data collection efficient? Are the technologies efficient? Fishery data are usually valid for a given and limited period: are the data that will be needed for management decisions in the future being defined now, and base rates established for subsequent use?

The problems of fishery data collection have scarcely been recognized in many parts of the world, let alone resolved. A better recognition of the full complexity of these problems would be useful and might lead to a serious reconsideration of the question of what data should be collected, and why.

It goes, nearly without saying, that much of the information needed to understand and manage a fishery is not now being made available to managers (we treat the matter generally throughout this report and specifically in sections 4.3 and 4.4). This is partly because fisheries management has not yet taken advantage of advances - in efficiency and in terms of cost - in the state of the data processing art.

When this state of affairs changes for the better and information is reliably and routinely assembled, the information must be interpreted. What does it mean? For what groups is it important and why?

Regardless of improvements in the technology of data processing, it must be accepted that fisheries management decisions must often be made on the basis of incomplete information. For instance, actions taken to determine levels of fishing mortality may be based on information about natural mortality, catchability, growth and recruitment. It is an unfortunate fact of life that some of these are extremely hard to measure. Very little is known about multi-species fisheries or the underlying economic dynamics responsible for the fisherman's behaviour. Even less is know, practically or theoretically, about the increasingly important social, political and legal aspects of the management environment.

Nevertheless, on the basis of the best information available, specific actions must be decided on and taken - the next step in the process. At this point expectations about performance need be established. In the case of fisheries management these can take the following familiar forms:

- Attain a specified catch.
- Achieve specific levels and kinds of effort
- Reach specific economic goals
- Achieve certain levels of enforcement efficiency

And so forth.

Where fisheries management differs at this stage from management in general, is in the absence of a single integrative and summary statistic (such as an annual profit-and-loss statement) by which to measure performance. Because of this and because of other previously mentioned difficulties concerning units of reference, data collection and so forth, it is less certain that management will proceed to the next step: evaluation. Even if it does so, the process may not be effective in its primary purpose of determining whether the expectations, developed earlier, have been fulfilled and if so how this came about and who was responsible.

Evaluations of internal efficiency and effectiveness must also be made. These take the form of budget reviews, audits, manpower reports and other procedures reflecting traditional public sector concern for accountability. Evaluation of these facets of management are particularly important for fisheries, for two basic reasons: relative to the task assigned, management budgets are seldom lavish; and many fisheries management activities (e.g., enforcement) are expensive.

Also required is "response evaluation" - an assessment of what external demands and pressures do to the effectiveness of the management unit or institution. Here the aim is to determine the extent to which management effort is diverted to "fire fighting" and crisis control - to episodic but unpredictable occurrences within the manager's field of responsibility. Examples of such impacts abound: major oil spills affecting shellfish or other species; international or inter-sectoral diplomatic conflicts such as the Cod War between several Atlantic fishing nations. Events of this kind inevitably affect the marshalling and disposition of management resources and the effects must be evaluated.

The most difficult thing to evaluate is the impact of fisheries management decisions on the encompassing environment, especially the fish stock themselves. Accurate monitoring of the abundance of the stocks is not easy, and the natural variation in abundance may often be greater than the expected impact of the management actions.

3.2 Differences between the general- and fishery-management models

Up to this point we have emphasized the similarities between fishery management and management in other fields. At this point let us consider some characteristics that set fishery management apart from the others.

To begin with, the fishery manager confronts and must reckon with a wider and different cast of characters in the course of his work. These include individuals and institutions who have long established and clearly defined roles and intents - e.g., research directors and their staffs, fishermen and others. But the addition of many newcomers, and an increase in the importance of some of the longer-established inhabitants has multiplied the interactions involved in fisheries management. It is necessary to pay attention to views, interests and objectives represented by these parties although they are seldom concurrent and quite often are competitive, antithetical or in conflict.

In general, the chief executive officer of a commercial company does not need to deal with so large a number of participants. Nor is he handicapped by the lack of authority and control over these individuals (and the resources they command) which inhibit the fishery manager.

Another basic difference is the way in which responsibilities are diffused and decentralized to a far greater extent than in most other settings. An aspect of this is the poor status often accorded to the fishery manager in many national structures. He may have little control over many decisions - e.g., investment in new vessel construction - taken by private enterprise or government institutions that will profoundly affect the success of fishery management. Another aspect is in the technical support he receives. If, for instance, in the corporate world there are shortfalls in the collection of business intelligence resulting in reduced ability to compete, the chief executive officer can take remedial action; beefing up the data-gathering and analyses functions, or perhaps even firing those responsible for the poor performance. These measures are not as readily available to the fishery manager. For example, in several countries the scientific research into fish stocks is grouped with general agriculture research, in an administrative unit entirely separate from the fisheries department. However, to make fisheries research the direct responsibility of the manager can also have serious disadvantages. Depending upon the state of the fisheries and the calibre of the manager, situations can arise where research becomes entirely responsive and crisis oriented. Thus, there is little or no progress towards long term management and little satisfaction for the research worker.

The fishery manager therefore cannot directly order additional studies or research or changes to existing programmes; whatever additions he gets will be the result of long and delicate negotiations with more or less independent research units. Even when these have been completed the "fit" between what the manager needs and what the research unit thinks he needs will not be precise.

In short, the environment in which business decisions are formulated and carried out is far more understandable and far less complicated than the world of the fishery manager. While a business manager can do what is necessary and feasible to control the environment (through market domination, monopoly, oligopoly or other manoeuvres), and thus reduce the uncertainties, the fishery manager's power to control is diluted by a need to win the cooperation of others. For instance, law in many countries demands that objectives be developed through the media of public hearings, collective negotiations and other mechanisms designed to ensure broad participation. One result is an enhancement of democratic

principles. Another has been to reduce the ability of the manager to force the management process forward. 1/

Compared with the businessman, the range of options presently available to the fishery manager are meagre, often being restricted to narrowly defined controls such as closed seasons, or limits on the sizes of fish that can be landed.

To be successful, the options open to the fishery manager need to be widened, so that he has greater opportunities to influence, even if he cannot control, the more fundamental decisions affecting the fisheries, e.g., on investment in new catching capacity.

Another telling difference is in the ability to anticipate problems and to respond flexibly. The traditional business manager strives, with varying degrees of success, to attain a predictive model of his environment and to exert maximum control over that environment in the process. Present institutional and political arrangements are seldom conducive to rapid or flexible responses by fishery managers to changes in the stocks, and the kinds of information presently available do not provide early warnings of change. Consequently the fishery manager, far more than the business manager, must operate in a reactive mode, responding to changing events as well as possible, with limited resources or authority. In dire situations this mode becomes one of crisis management in which decisions must be made, almost spontaneously, from a very limited set of alternatives and in situations where only very large expenditures could have any impact.

1/ It may even result in actual decisions being reached that are totally beyond the control of the manager - decisions which, furthermore, contradict the spirit and specific intent of the management process. For example, in lengthy discussions (read "define the objectives") about limited-entry schemes, fishermen will often anticipate the limited entry decision by building new boats as rapidly as possible while the management process bogs down in its initial step or phase.

4. Component Problems

The previous section has outlined the components of management in general and in fishery management in particular. This section examines each of the components individually. It discusses the nature of each component and identifies the major problems that need to be dealt with at each step. It should be read in conjunction with the next section, which looks at the process as a whole, and the need for a balance between what is done at different stages.

4.1 Definition of objectives

As in other activities, the establishment of a clearly defined objective, or set of objectives, is an essential starting point for fishery management. The declared objectives will govern the detailed nature, scope and content of the management schemes that are adopted, including the requirements for data and research, and they provide the yardstick against which the success or failure of management can be assessed.

There has been considerable debate regarding the appropriate definition of a fishery management objective. Discussions on an appropriate objective have intensified with the changing legal regime. Before these changes in effective ownership, marine fisheries were international, based, with few exceptions, on common property resources. The fisheries of the different countries taking part in the overall fishery activity were governed by different social, economic and political climates. As a consequence, and not surprisingly, the objectives of fishery management which became most acceptable to the international fishery community, and which were embodied in international fishery management conventions, were ones defined on the basis of criteria relating to the biological properties of the exploited resources and the catches attainable from them.

The most widely used objective was maximum sustainable yield (for definition, see Appendix 4) or some variant of it. The merit and attractiveness of maximum sustainable yield was its apparently unambiguous definition, its focus on the maximizing of fish production for food and industrial purposes, and the fact that it could be estimated - at least to a reasonable approximation - with the scientific tools available. It was frequently the upper bound for a range of advocated strategies and thus a basis for compromise. When the simplified context of MSY calculations is altered to allow for species interactions, climatic trends, and alternative definitions of benefits, it is no longer a simple matter to define and calculate MSY.

Biologically-based objectives such as maximum sustainable yield may result in a management system which "works" and achieves benefits to the community in the form of higher sustained fish supplies than would probably be attained in the absence of management, but the biological objectives in themselves do not satisfy specific important socio-economic concerns in fishery management. As has been pointed out by fishery economists for many years, management based on a biological objective such as MSY will inevitably result in over-capacity in the fishery and the dissipation of the potential economic benefits which might be achieved if "optimization" involved socio-economic objectives with biological constraints. Economists argue that an objective, aimed at maximizing economic yield (for definition, see Appendix 4), would be more appropriate than the biologically based one. The result of doing so might be some sacrifice of average physical yield from the particular stock in question, and in the level of direct employment in that fishery, in return for more long-term stability in the fishery and an increase in the contributions made by the fishery to the economies of the participating countries. Many other objectives have been advocated on some fisheries management situations. These include maximization of employment or achieving target levels, maximization of export earnings, achieving a target income distribution and maintaining high catch rates for recreational fisheries.

It is often the case that management must entail simultaneous consideration of multiple and conflicting objectives. This is only natural given the complex interactions of the groups harvesting and utilizing many stocks. There are two ways to handle this. One is

to place relative weights on each objective so that they can be combined. As a hypothetical and quite simple example of this consider the objectives of maximizing net income to the industry and maximizing net foreign exchange earnings. If the second is considered only half as important as the first, the weighted objective would be to maximize the sum of the net earnings of the industry and one half of the net foreign exchange earnings.

The other method is to state some objectives in the form of constraints. In the above situation this could be done by striving to maximize net income to the industry subject to the constraint that net foreign exchange earnings remain at or above a certain point.

Some clarification is in order at this point. First, objectives are usually quite difficult to measure (although, as stated above, an integral part of a good objective is a measurable success parameter). Even so, the principles of relative weights and objectives stated as constraints are valid. Conflicting objectives have to be directly faced for management to be a success. A second point is that determining the weights or the types of constraints can be difficult. It is most likely an issue that should be addressed at a legislative or senior policy level.

The changes in the legal regime have made it possible to give more attention to non-biological objectives.

The Working Party recognizes that because of the complex biological, economic, social and political factors involved, which change with time and the "state" of the fisheries, it is probably not possible or advisable to attempt to define a rigid, universally applicable objective of fishery management. It does, however, consider it essential, if fisheries are to make their fullest contribution to society, that socio-economic and political factors and criteria are taken into account. This must not be taken to mean that biological factors and criteria can be ignored, or assigned a lower importance. On the contrary, it is essential to maintain the resources in healthy and productive state, through effective resource management. Unless this can be done other social and economic benefits cannot be obtained from the use of the resources. Therefore it is necessary, to ensure that the objectives take into account the whole spectrum of factors operating within the fishery; failure to do so may result in undue attention being given to only part of the fishery problem and the concentration of the management activities (including funds) in arriving at optimal solutions to only a part of it. It is, however, also necessary to avoid the potential pitfall of this all-embracing approach, of defining management objectives in too idealistic a manner so their meaning is ambiguous and provide little or no operational guidance. In particular, one criterion for objectives is that they are sufficiently well defined to be used in the final evaluation stage of the management process to check whether management is being successful.

Reduction of conflicts is an objective of management which has received little explicit recognition, even though it is implicitly one of the most important objectives of fishery administrators. The general need for management arises from conflicts between long- and short-term interests, and between interests of individual fishermen and those of the fishery as a whole. Conflict frequently arises where two fisheries influence the abundance of several resources but where the relative value of these resources differs between the two fisheries. The conflict between industrial and human consumption fisheries is an obvious example, but the same effect occurs even with fisheries competing for a simple resource where the size of fish preferred by one fishery differs from that of another so that the activities of a fleet which exploits younger age groups has an important influence on the success of a fishery exploiting larger (older) age groups. In this situation the clear recognition that the main objective is resolution of conflict and not, say, MSY, can be the key step to a solution.

4.2 Definition of units and boundaries

Recognizing the elements to be managed is important. The definition of the elements of the system deserves careful attention because of the implications on data gathering and analysis. These elements can relate to the stocks, the fishery, or the industries in

general. Setting boundaries that are too narrow, and units that are too small may lead to ignoring important relevant facts. Setting too broad boundaries and too large units can lead to such complex situations that it is impossible to come to clear decisions.

The boundaries and units used need not be the same for all purposes, particularly when collecting and analysing data. For example, when considering the possible management of a trawl fishery catching cod, the biological analysis should consider that stock of cod wherever it occurs, and whoever catches it; the economic analysis may consider the world market for cod, or for groundfish generally, and an operational analysis may consider all alternative stocks that the trawlers in question could exploit if cod fishing were controlled.

4.2.1 Biological units

The question of definition of units is often raised in the context of biological boundaries. Management has to be related to unit-stocks of the separate species (see Appendix 4). The range is determined by the movements of each species and varies from the very extensive range of, for example, whales, tuna and salmon to the very restricted localization of individual coastal stocks of flatfish and crustacea. It is unusual for the distribution of stocks to coincide with man-made boundaries.

The unexploited and the exploited phase of a stock may be distributed within the jurisdiction of one or more states and, in more complex situations, different phases of the exploited stock of the same resource may occur within the jurisdiction of different states. All these circumstances lead to situations where the fishing activities of one state, or its associated activities in utilization of the marine environment, may influence the fishery management regime of another state so that the management of the resource requires cooperative action.

The question of the biological units to be considered is becoming further complicated by the range of species being exploited, and the greater intensity of exploitation of these species. This has made it more likely that the fishery on one species will affect fisheries on other species, and that these effects should be taken into account in managing the first fishery.

4.2.2 Social and economic units

Fishery management comprises all the decisions taken by administrators that affect, directly or indirectly, how fisheries are carried out. Management concerns itself not only with the application of restrictive measures - size limits, catch quotas, etc. - but also with fishery development (in the sense of activities that stimulate increased or more efficient fishing). Fishery management should be planned and work in close coordination with development activities, especially when governments can influence significantly how these activities proceed. Many present-day management problems have occurred, or are as difficult as they are, because of earlier failures to adjust the growth of a fishery to what was known, or could reasonably be surmised about the stock being exploited. Once fishing capacity has exceeded sensible socio-economic limits, and there are more ships and fishermen than can be successfully supported by the resource, the process of retrenchment to a more rational level is bound to be painful. Possible methods of retrenchment are given in Appendices 1 and 3.

A failure to include fishing development policies as part of fishery management is essentially a matter of setting the wrong boundaries to the problem, and taking too restrictive a view of what should be examined. Such a failure was understandable, and to some extent inevitable, in the traditional open-access free-enterprise fisheries such as those of many countries bordering the North Atlantic. The decisions that affected the development of these fisheries were taken by individual fishermen, or individual companies, and there was little opportunity for national administrations to affect the course of these developments until development had reached the stage at which restrictive measures (i.e., fishery management in the narrow sense) became necessary.

This is less true of many fisheries in developing countries. Development in these countries is often undertaken as part of large-scale national plans, frequently with support from international development banks.

The Working Party therefore paid attention to identifying the range of interests involved in fishery management, and the individuals or groups of people that actually or potentially influence the management process. These could be illustrated in two diagrams showing the flow of information and decision. Figure 2 is a schematic representation of information flow from the resource and industrial sectors, through or past technical advisers to a number of interest groups who may adopt policies and attitudes which directly influence industry, or which influence decisions made at a political level. The list is not exhaustive, nor are all groups represented in all fishery situations and there are additional information links, particularly by "vertical" communication between sector groups but the lines indicated do show a fundamental horizontal stratification. There is a major flow between the extraction process and its downstream activities to secondary industry, financial resources and government departments with an indirect and broad societal interest in the fortunes of the fishery industry. There is a second stream of information concerned with the availability of the raw material as a renewable resource flowing from technical advisers to fishery administrators. This group has the broadest overlap of interest relating raw material supplies to policy in the dependent industry. But it is noticeable that very little information on raw material supply is solicited by or readily available to the secondary industry and investment areas which have a profound influence on the development of a fishery.

Figure 3 sets out the complementary patterns whereby decisions may influence the development. Again this is not exhaustive but again it illustrates stratification. Financial institutions, secondary industry and related government departments can and do influence the level of exploitation directly and in a way which is not responsible to the administrators implementing a fishery management policy except through the overall political decision process. It is also evident that the decisions which influence the rate and level of expansion in fishing are as highly fragmented as the industry itself.

A clear identification of the extent of interests in the fishery and its management is particularly important at the stage of taking decisions. It is essential that all those that have an interest - and often also those that feel they have an interest - do participate. A good example of the results of failing to do this is provided by the grey seal problem in Scotland. The failure to recognize the extent of the interests in seals of the public in general, and conservation groups in particular, and their omission from the initial decisions to reduce the seal stocks led to great political difficulties when the decisions can to be implemented.

In summary, the boundaries within which the problems are to be treated may need to be flexible, and different boundaries used for different purposes, and at different stages, but the following points should always be examined:

(i) is the full geographic extent of the resource(s) involved?

(ii) have other biological influences, particularly those of other exploited species, been taken into account?

(iii) have all economic and social factors that could affect the fishery been examined?

(iv) are all interests involved in taking decisions?

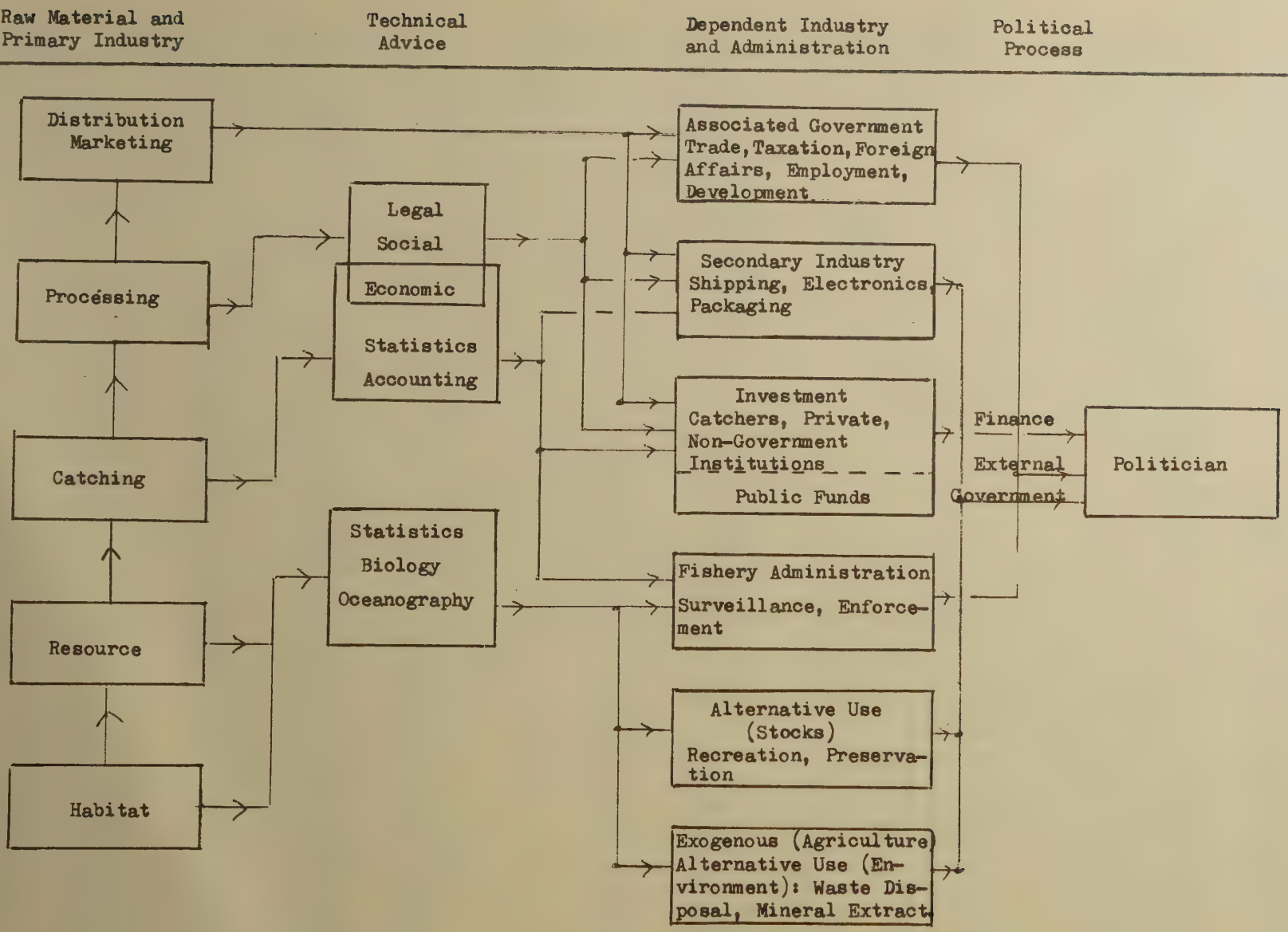

FIGURE 2. INFORMATION FLOW

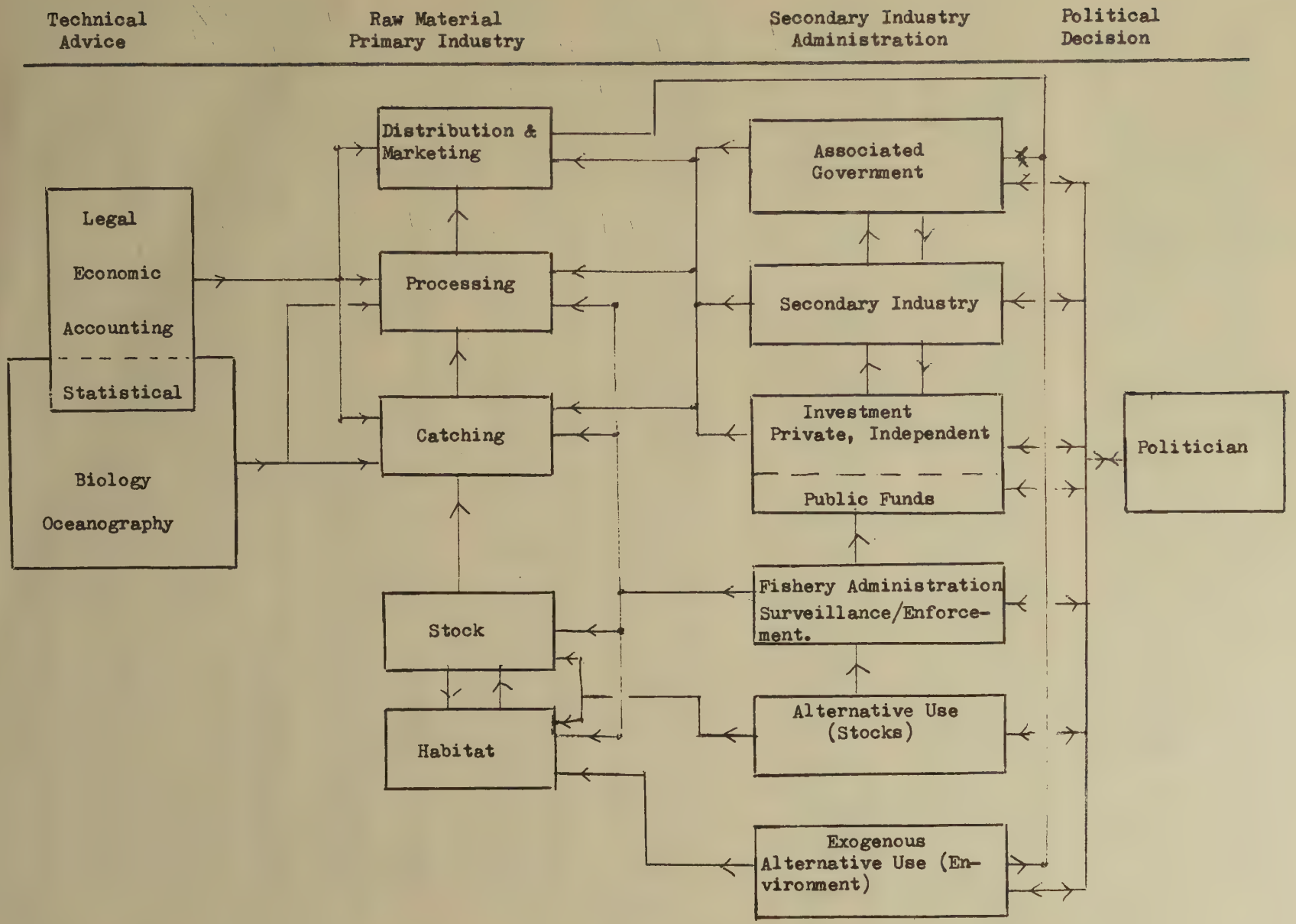

FIGURE 3. MANAGEMENT INFLUENCE

4.3 Collection of data

Data should not be confused with information. Data comprise the collection of facts, observations, etc., which require editing, processing, interpretation and communication before they may be considered as usable elements of information. The data required for fishery management are currently drawn from a variety of sources. Often they have been collected for purposes quite distinct from their usefulness to the fishery manager. Where there is a separation between those who use the data, and those responsible for collecting the data, there is bound to be a risk of the wrong data being collected, or the data being in other ways inadequate.

Inadequate data, whatever the cause, can have serious consequences. Many, if not most, failures in fishery development programmes are traceable to the lack of adequate data, especially concerning resource assessment. Similarly a common reason for measures to manage or conserve the resources being applied too late has been the lack of adequate data. A major impediment to development of adequate systems has been the failure to define requirements in terms of reliability, timeliness and accuracy, on a cost-benefit basis.

Resource assessment is an aspect of fishery management which is particularly sensitive to poor data. Fish stocks are not visible in the usual sense of the word, and their assessment must be made by indirect means. These indirect means require varying amounts and kinds of data which often need to be available for a long period covering the development of the fishery. Convincing administrators and planners of the importance of programmes to obtain these data, rather than other more "visible" projects is one of the more difficult tasks facing the fishery manager today.

The varied types of data needed for the understanding of the stocks, or concerned with harvesting, processing, distributing and marketing can be classified in various ways. A common method has been in terms of the discipline (biology, economics, etc.) primarily concerned. For the present purposes it may be better to classify data according to the ultimate user, and the type of management activity involved, as follows:

(i) Immediate management. The monitoring of the fisheries against the prescribed objective or goal. Examples are:

Biological: catches per unit effort
Technological: production and sales of specified products
Economics: costs and prices.

(ii) Preventive management or "safe-fail" information, required to determine the likely occurrence of disturbances to the system.

Biological: changes in environment; recruitment failures
Technological: product quality, demand
Economics: rate of capitalization; investment.

(iii) Remedial management. Data involving a variety of technical information to facilitate improvements.

Biological: means of predicting year-class strengths
Technological: effect of vessel design on product quality
Economic: costs of limited entry alternative.

(iv) Research and development. Data acquisition which covers the broad range of fundamental and applied research in fisheries designed to solve problems identified within the previous categories.

Other implications and features of the data - information problem are treated in Appendix 6.

Some management practices could be modified to provide clear incentives to providing improved data. For example, if, in the case of inadequate data leading to inconclusive advice on the level of TACs, the more conservative estimates were always taken, there would be an immediate incentive for those wishing to take larger TACs to supply better data. Current practices sometimes work in the opposite direction.

Data processing consists of the editing, standardization, reduction and storage of the input material, and the generation of reports and other outputs in forms suitable for the user. It should be recognized that while data are ordinarily defined as facts, frequently input data are observations or interpretations of highly variable validity. It is important that account is taken of the nature of the input data.

Because of the wide variety and number of sources of data potential useful to the fishery manager, he can easily be unaware of relevant data. A catalogue of what is, and what is not, available is therefore an important part of any data system. Since there are frequent changes in the staff responsible for data handling in many institutions, such a catalogue must include careful documentation of how the data were collected, how they have been processed, and the forms in which they can be made available to potential users.

The technology of data processing and information retrieval has recently advanced very rapidly. In the business and industrial community decision-makers are now being supplied automatically with reports in which up-to-date information is presented in the forms closely matched to their particular requirements. In contrast fishery managers have given very little attention to using an appropriate selection of modern technology.

4.4 Extraction and interpretation of information

Timely information is vital to successful management. As early as 1971 an OECD report stated "Perhaps the most important event of the next decade will be recognition of the value of information - the right information, reliable and relevant to our needs, available in a useful form to all those that need it." In many areas the appropriate information communicated on a timely and acceptable basis is considered as the most valuable commodity of management.

The key characteristics of useful information have been communicated in a variety of publications and most succinctly in respect of scientific information for fishery management in an ACMRR report of 1974. This listed in order of priority the following attributes:

1. Scope and relevance
2. Timeliness
3. Clarity and ease of comprehension
4. Accuracy and precision.

These qualities should be borne in mind whenever data are being processed to provide information and advice. Converting data into information involves a translation and interpretation step that requires human intervention. What does a time series about fluctuations in fish stocks actually mean, to whom, and under what conditions? The answer may vary from place to place, person to person, and from time to time. It will certainly vary according to the overall purposes or objectives that have been established and/or which guide the individual and institutional participants in the process. In any case the purpose of this stage in the management process is to provide those involved in the next (decision-making) stage with an understanding of what has been happening in the fishery in the past, clear information on its present status, and predictions of what is likely to happen in the future under different situations.

4.4.1 Models

The requirements to understand the fishery, and to predict the likely effects of different management actions can in principle be fulfilled by using models of the fishery. In using models, however, one is inevitably faced with a dilemma. For models are, by

definition, simplifications of a complex reality. Excessive reliance on oversimplified models can lead to the failure of the management programme, but sophisticated, "realistic" fishery models are seldom feasible because of their extensive data requirements.

Traditionally the greatest use of formal mathematical models has been in the biological studies of the effect of fishing on the stocks of single species of fish. These models of fish population dynamics, which are described in the fisheries literature, include the well-known stock-recruitment, general production, and cohort models. Standard procedures exist for estimating the parameters for these models from fishery data. These estimates then lead to certain predictions (of either a static or dynamic nature) - e.g., maximum sustainable yield, or recovery rates under various management policies.

In many situations, however, a more sophisticated model may be desirable. For example, the decision-maker may wish to know to what extent a fishery on one species will affect, or be affected by, fisheries on other species. Or estimates of the variability of recruitment may be desired in order to plan appropriate processing capacity, etc. Fairly complex bio-economic models may be wanted, both for the purpose of determining optimal catch rates and for predicting the response of the fishing industry to various types of regulation.

Recently considerable attention has been paid, in various meetings and workshops, as well as in the scientific literature, to the types of models that are now available to deal with the more complex situations such as multi-species fisheries. The general consensus emerging from these meetings is that there are now models that can give considerable insight into the qualitative nature of the interactions that occur when several species of fish are exploited at the same time. However, the present state of knowledge is such that the models cannot yet be used to give quantitative predictions of the effect of changes in the pattern of exploitation of one species on the stocks of other species, and on the fisheries on those species. The main difficulty is the need for extensive data to apply the more realistic, but more complex, models. The need therefore is less for developing new models than for research leading to a better understanding of the biological interactions among the exploited stocks and improved data collection.

Developing a model of sufficient complexity to deal with the interactions between several species will normally be a major undertaking, the expense of which would probably be justified only for a large, economically important fishery. In particular, in contrast to the models of the population dynamics of single species there are no "standard" multi-species models, stochastic models, bio-economic models, etc. that can be routinely brought into play. Each fishery is likely to have unique characteristics, requiring specific models. In practice, a less rigorous qualitative (or even verbal) approach will be more appropriate in producing information to the decision-makers.

Modelling also has a role in the collection and analysis of data, though this is frequently ignored. A formal quantitative statement, i.e., a model, relating the design of alternative sampling programmes to the usefulness of the resulting information can be an effective tool in planning and evaluation. Sensitive parameters can be identified and sampling effort redirected if necessary. This type of modelling is distinct from the building of analytic models for prediction and policy analysis.

However, in practice, regardless of the models used, the actual behaviour of fish stocks and marine ecosystems will probably always remain unpredictable to a significant degree. Consequently management must always be prepared to deal with unexpected events. For example, large catches of one species may lead to unanticipated reductions (or increases) of other species, with the result that quotas of both species will need to be adjusted. On the other hand, environmental changes may suddenly alter the supply of a certain stock. In some instances, these changes may occur very rapidly, especially if there are unknown "thresholds" of abundance. Unless the management regime includes rapid monitoring and transmission of relevant data, irreversible losses of important stocks can occur before appropriate action is taken.

4.5 Formulation of action

So far we have attempted to define the configuration of the biological, economic and social resources to be managed, potential objectives have been identified and data collected and organized to provide the information base on which policy and action can be decided. This logical hierarchy in the development of management is attractive in principle, and much can be achieved because the first three elements can be made the responsibility of relatively small numbers of people trained for the purpose. The reality of deciding management policy and management action becomes much more difficult. The streams of information and the aspirations of different interest groups have to be drawn together to formulate policy and action which will not necessarily be equally acceptable to all the groups within a state, and still less will they be acceptable to all groups between countries involved in the exploitation of shared stocks. Not only do the interests vary, but, as pointed out in Section 2.1, the national interests may not be consonant with the interests of individual components.

It must be recognized that external factors frequently force fishery management into a responsive mode. This leads to piecemeal and incremental introduction of regulatory measures. These imply increased government intervention in industry and resolve short-term problems at a possible long-term cost of lost efficiency. Broad policy should not be lost sight of under the pressure of incremental decision-making.

4.5.1 Choice of action

The discussion so far has been concerned with the process involved in formulating action, and the need to take account of all interests, rather than with the nature of the actions taken. It must be stressed again here that, if the current state of the fishery is governable, these actions may well be to develop the fishery in the sense of building more trawlers, adding a freezing plant, or granting low interest loans to fishermen wishing to build a new vessel. These development actions are just as much management decisions as restrictive measures. Regulatory options to fishery management have been considered by Anderson (Appendix 1), who discusses four different methods of controlling the amount of fishing by limited entry. He lists 13 criteria, in no particular order of priority, that can be used to judge between methods, as follows:

1. Implementation: How easy is it to introduce the necessary legislation, and set up the necessary regulations?

2. Flexibility: How well does it cope with unexpected events, e.g., the occurrence of a very bad year-class?

3. Other types of regulation: Does it need other regulations to make it effective?

4. Intra-fishery conflicts: Does it help resolve existing or potential conflicts?

5. Multi-purpose fleet: Can it accommodate vessels fishing at certain seasons for other species?

6. Distribution: Does it promote a desirable pattern of distribution of benefits between participants?

7. Prices and employment: Is its influence on these in the right direction?

8. Biological goals: Can it ensure that the basic biological goals, especially maintaining the stock, are achieved?

9. Interdependent species: Can it deal with the interactions with other species, and the fisheries on those species?

10. Vessel efficiency: Can the vessels in the fleet maintain their efficiency?

11. Technological advance: Does it encourage a reasonable rate of technological improvement?

12. Research and regulations costs: How does this particular form of control affect these costs?

13. Freedom of individuals: How much freedom is left to the individual as to how he fishes?

These are not put forward as final or ideal criteria - some may overlap, and others may be inappropriate in different national settings - but they are put forward here as an example of the type of criteria which can be used. Fishery managers may find this list to be more generally useful.

Almost certainly no one measure will be best by all criteria, and the ideal measure for a given situation will be that which best satisfies these criteria, according to the preferences of the particular situation.

These are likely to change. For example, there seems to be a change, taking the world as a whole, in the balance between the two principal ways of measuring the amount of fishing - by catch or by nominal fishing effort. A few years ago, when most important fisheries were international, catch was the preferred measure, principally because it provided a clear unambiguous comparison of the relative amount of fishing by different groups of fishermen. Now that most fisheries are under national control, the advantages of effort as a measure (e.g., less distortion due to variations in stock abundance) particularly in combination with controls on catch, are becoming more apparent.

4.5.2 Timing

Fishery management measures fall in two categories, those concerning the technical characteristics of fishing vessels and gear and regulations concerning the amount of fishing or catch from different resources. The first are intended to remain in force indefinitely, the second group need to be reviewed annually owing to the intrinsic variability of fisheries. This annual review procedure and the precision and efficiency of the decisions made are heavily dependent on the provision of data, its analysis and the development of advice on a time scale which enables the decision to be ratified and notified to national industries early enough for them to make appropriate adjustments for the regulatory period in question. The time scale of these procedures frequently creates additional difficulty and uncertainty in a process which is already complex. The manpower made available to support fishery management must be appropriate to the time scale of the review procedure and the size of the management area involved in each review. Again, for example, the data-processing and analytical facilities of most countries and their administrative machineries at present necessitate a two-year lag between the time of collection of the original data on which a regulation will be based and the period to which a regulation will apply. This is a situation where, for some resources, the data crucial to estimate the potential catch in a regulatory period can at best only become available toward the end of the year immediately preceding the regulatory period. Careful attention must be paid to these time scales of the management process if the management measures are to achieve their objectives.

The essential problem at the "formulation of action" phase of the management process is to establish the institutional mechanisms wherein the necessary dialogue between the various interests groups can take place in a timely fashion, combining all the available sources of data and reviewing the policy options insofar as it is proper and relevant for the various groups to do so. It may indeed be inappropriate to consider these matters in a single forum if the groups are themselves involved in competition within the system to be managed.

4.6 Execution of management

Management policies and plans however well formulated and sound are of little value unless they are efficiently executed. Efficient execution of management policies and plans involves the application of basic techniques of organization management. These include communicating the policies and plans to both those who are affected and those who must carry out the plan; setting work schedules; assigning personnel to the various tasks that comprise the plan; developing budgets and monitoring the performance to make sure that the various activities correspond to the stated policy and plans. While these steps are well known, they are not always efficiently performed.

In addition to following standard management practices, the execution of fishery policies and plans requires consideration of special problems that almost always exist in the fishery management setting. These include:

(1) making sure that the operators in the fishery understand the plans and policies;

(2) ensuring that plans are translatable into actions that can be monitored and that the costs of monitoring fit within the budget of the management activity, and

(3) structuring enforcement so that it is consonant with the objectives of management.

4.7 Evaluation

Evaluation is an essential component in any management regime, but of special importance in fisheries where the manager is often not in direct control of crucial, determining elements. In fact, the fishery manager finds that he is often reacting to events, but doing so without benefit of evaluation mechanisms.

More to the point, the fishery manager needs to be mindful of three distinguishable forms of evaluation, each of which contributes to his overall ability to understand, assess, and react to problems and opportunities.

Managerial resources are seldom lavish; therefore, efforts must be expended to ensure their efficient and effective use. Internal auditing, accountability, (managerial) control, and other tools and techniques are available and must be used to enhance administrative practice. In common usage, these are referred to as process or internal evaluations.

One must also know the effects on a fishery management institution of external demands, threats, and opportunities. For instance, in the case of an unexpected conflict or dispute, sacrifices in the total managerial programme may have to be made in the interests of additional monitoring, surveillance, and enforcement associated with the dispute. The results of such sacrifices in terms of the outputs of other activities, e.g., resource evaluations, must be determined. Likewise, to what extent are high-visibility, short-term problems deflecting attention and resources away from less visible, longer-term, but possibly more consequential ones? Such considerations - and the means taken in their resolution - are known generally as response evaluations.

Determining the effects of management actions (including inaction) on the decision setting or environment is a third type generally known as impact evaluation. Who or what is responsible for successful and unsuccessful results? Can they be recognized and rewarded to enhance and encourage performance, in the first case, or to correct and ameliorate, in the latter? What are the proximate and longer-range consequences of management actions (or inactions)? Determining managerial impacts is often very hard to do or to do well; this fact ought not discourage its prosecution, however. The explicit use of outside and consultative assistance is often indicated to improve the scope and objectivity of the evaluation.

The concept of impact evaluation is explicitly comprehensive: one works to assess the impact on the relevant whole of the management setting, not simply a few of its routine and commonplace parts. For instance, attaining an objective such as reducing the number of vessels harvesting a given stock of fish may be achieved through licensing or other programmes. However, the effects of reaching this objective may have the unintended consequences of increasing the absolute size and capacity of each remaining vessel and hence overfishing the stock and contributing to a variety of other undesirable outcomes. An impact evaluation aims to determine these consequences and to create mechanisms and procedures to improve matters.

Doing so-called "base-line" impact evaluations of the current status of specific management setting is a logical starting point for those responsible for it. Among other concerns, one would work to appraise the existence, extent and effectiveness of the overall management process (as characterized in this report): are there holes, redundancies, or other features that require attention, and if so, what remedial steps might be taken?

5. Making the System Work

The previous section described the main components of the fishery management system and the steps that should be taken to ensure the proper functioning of each component. However, efficiency in individual components does not add up to a smoothly-operating system. The pieces must fit together and balance. This section discusses the problems of making the system work as a whole.

5.1 Aspects of the fishery system

Fishery management is a complex process involving a large number of participants, each of whom views the system in a slightly different way, depending upon his particular interests and background. While the fishery manager may have a more comprehensive view of the system than other participants, many aspects of the system may remain obscure. The manager often lives in a world of unexpected results and indirect impacts.

Problem recognition is further impeded by institutional and disciplinary requirements and preferences. For example, biologists have acquired tools of observation and measurement that concentrate on certain important aspects of the system, but that do so within a relatively narrow focus.

The other disciplines involved, such as economics, sociology, law and the decision and management sciences, each have their own selected areas of emphasis and these may or may not overlap with those under scrutiny by the biologists. This situation is true not only of disciplines and individuals within disciplines, but of institutions and their own preferences and specialization. Their zones of competence or authority cover selected portions of the relevant "territory". When these zones overlap, problems of disputed authority often result. When they do not overlap they may, from the viewpoint of total systems efficiency, operate at cross-purposes.

A crucial part of the manager's role is thus to make sure that all relevant viewpoints are represented in a balanced way in management decisions.

The problem is largely one of communication - of the manager with each of the disciplines and interests involved, and of the latter with each other. In particular, the manager must be sure that his view of the situation is not dominated by the description that, in the current situation, appears to be of overwhelming importance. This hazard may take different forms at different times. When stocks are being heavily fished, the tendency is for the biologists' perspective to be dominant. In an earlier stage of development, before fishing or overfishing has begun in earnest, the tendency is to neglect the biologists' advice.

If the manager is to receive a balanced view of the whole fishery system and if he is to ensure that professionals in each discipline and interest group have at least some general understanding of the problems and interests of other groups, he must address questions such as these:

1. How do different elements communicate with one another?
2. How do the different elements see the general environment in which fisheries operate? Do they make use of their opportunities to affect this environment?
3. How do individuals obtain their views of the management system?
4. How do the involved individuals integrate their views?
5. How are actions developed and communicated?

Specific attention to these elements will not guarantee universal agreement between participants but they will reduce the number of artificial conflicts attributable to poor

communications. And with communication problems out of the way, the parties involved can work toward solving problems of substance, using mediation and bargaining processes, based on good communication.

5.2 Organization of the management system

Despite the limitations of authority and control under which the fishery manager suffers, as noted in Section 3.2, he still has a responsibility for doing what he can to see that the management system is organized well. This involves not only ensuring, as noted in the preceding section, that all interests are properly represented when decisions are made, but also that available budgetary and human resources are used in the most effective manner, and that there is, as far as possible, a proper allocation of authority. He must also realize that in some situations management objectives, however desirable, will be impossible to attain given the existing available funds. In other situations it will be found that not even the most generous budget can produce a feasible programme.

Human resources are also critical to the efficiency of the system. These can be characterized in terms of ability, training and disciplinary outlooks. Each management system will need a specific mix of individuals and it is a task of management to try to attain this mix either by recruitment or suitable training. Human resources must be provided with a substrate in which they can function effectively. Although this may seem self-evident the fact is that the operations of many fishery organizations are characterized by administrative practices which are, like most organizations, wasteful of time and energy.

Even under present conditions, it is clear that an imbalance in time, attention, and money expended exists with respect to the seven fishery management tasks or functions earlier characterized (Section 3.1). A disproportionately small share of these resources appears to have been spent on trying to understand and define the objectives of the system and to put into use units of observation and measurement that would enable one to monitor how well these objectives are being achieved. For example, if there are serious management shortcomings and failures of a non-biological character, merely collecting more biological data would somehow only worsen matters from a systemic perspective, although it may provide short-term comfort to the biologist-manager in terms of his being able to "do something' when all around him appears to be dissolving into chaos.

What is required, as a necessary first step toward intelligent management, is a thoughtful and honest appraisal of precisely how time and other resources have been expended with respect to the seven steps or tasks of fishery management. A necessary second step would be to allocate those resources so to provide more balanced and comprehensive coverage of all tasks expected of the modern manager.

From the system perspective many of the component tasks will necessarily be decentralized and/or delegated to others residing outside of the manager's direct span of authority or control. Often, where coordination of these compartmentalized efforts is called for, the manager is enticed or seduced into trying to do these jobs on his own. Most striking is the confusion of responsibilities that occurs at the connection or interface between the extraction and interpretation of information (which the manager can do on his own or with certain specialized assistance) and the selection of an option or options for execution (which is more often a politically specialized task or function). This comment calls into question the entire experience of "expert advocacy", whose dangers have been well stated thusly: 1/

> "If, in the guise of analysis and exposition, an expert becomes an advocate for a particular decision, he sometimes may have his own way, but only by substituting his own judgement for that of people who have the responsibility for decisions and

1/ U.S. Secretary of Defense Harold Brown, "Speech on the occasion of the Dedication of the Stennis Center," Starkville, Mississippi, October 21, 1977 (Department of Defense Press Release).

who might weigh values differently if given all the facts, and whose judgement may be better."

The current defects in understanding the theories, both biological and non-biological, involved in fishery management, intensifies the dangers of confusion of roles. Up to a point the manager may be content to follow blindly the advice put forward by his scientific advisors. This results in extraordinary pressures being exerted on the few scientists in the field who are able to analyse and interpret information and present it in a form on which action can be taken. In all but the most simple situation, however, the scientist will not be able to give direct and unqualified advice. When, as must necessarily often be the case, a decision-maker's query is met with equivocal and guarded replies derived from tentative and uncertain models of systems only vaguely understood (even with regard to their narrow biological aspects, not even concerning other important non-biological ones), the prevalent tendency to dismiss or overlook scientifically-based advice becomes all the more understandable. The result can easily be that, failing to understand the problems faced by his technical advisors, the manager tends to take one or other of two unsatisfactory options - complete acceptance, or complete rejection of the advice. This inevitably leads to sub-optimization and mis-specification which currently dominate the fishery management field; these are system problems of the highest order.

Learning, flexibility and adaptability are related, systemic problems. In Section 3.1 especial stress was placed on the need to evaluate performance with respect to efficient internal workings, effects sustained by the organization as a result of external events, and with respect to the organization's impact on its operating environment. We sincerely believe that raising and answering questions about these aspects of fishery management would produce very beneficial results with respect to learning, flexibility and adaptability. Such is not happening anywhere within the system at the present time, and the results have been stunning. Apparently well-conceived management plans either do not work or they produce results that were neither anticipated nor desired, e.g., foreign fishing fleets have been restricted in waters offshore of the New England fishery, but operational problems are scarcely lessened, rather they have been magnified and blame has shifted away from rapacious foreigners to meddlesome government. To the fisherman, matters are not better, and they may even seem to be worse. The system has not been responsive to the real demands of the management setting.

5.3 Other system problems

5.3.1 Regional fishery bodies

A view of the fishery management process as a system suggests an important new role for regional bodies. The establishment of EEZs has increased the fisheries opportunities and responsibilities of national governments. It has also increased the need of these governments for a forum in their regions in which they can discuss common problems, exchange views and coordinate action.

The provision of scientific advice is likely to be a central feature of these emerging regional bodies; they can provide a central data store (especially when several countries are exploiting the same stock). In this regard the need to share the costs of expensive scientific research studies and data collection means, e.g., scientific research vessels, is particularly relevant.

Regional bodies may also provide a better opportunity for scientists and others involved in fishery management in the countries of the region to discuss problems - to review analyses of the state of resources and to look at the effects (including, if possible, economic and social effects) of different management actions. Increasing demands for advice suggest that there will almost certainly be a need to strengthen existing secretariats of regional bodies throughout the world, and to create new ones where they do not now exist. Regional bodies could also provide advice and guidelines on such matters as the standardization of data collection and compilation methods, and on the exchange of data between countries, both within the region and internationally.

Within their general role of providing a forum for discussion, regional bodies can also act as arbiters between different parties, e.g., on the interpretation of scientific data where this is used to set total allowable catch and other allocations between countries.

5.3.2 Training

One of the most obvious weaknesses of fishery management is the shortage of suitably trained people. There is a shortage not only of good managers, but of specialists in the component disciplines. Training of managers is addressed in Appendix 2, which deals with an International Institute of Fishery Management. The purpose of such an Institute would be to expose the world's fishery managers to the collected and accumulated wisdom on issues of central importance, and to provide the most extensive training for those likely to take up management positions in the future.

Training curricula for specialists usually gives scant attention to the role of other specialties involved in the system. Fishery scientists cover the biology of fish and the ecoosystems in which the fish live. They learn relatively little about the specific biological information needs of fisheries managers, and how this information needs to be presented. This is not wholly due to a shortage of suitable training material. A number of FAO manuals, among others, deal with several technical problems - collection of statistics, resource surveys, stock assessment, etc. - specifically in the context of fishery management. However, they do not appear to be as widely used as their generally accepted technical excellence would warrant. Further, they are incomplete, predominantly dealing with the biological aspects of management. Much needs to be done to ensure better use of existing material, production of further material, and better training generally and this is a task of overall management. It is less easy for, say, the director of a biological research institute to identify shortcomings in biological training that affect the quality of advice, and to act to rectify this.

5.3.3 Changes in the system

A final observation from a system viewpoint is that the environment is not standing still, it is dynamic, has fluid boundaries, and will vary in particular detail from place to place and over time, even for the same place. The fishery management system is never in equilibrium: stocks of fish fluctuate and the cast of characters associated with any specified resource will change through time and in response to a host of conditioning events and factors. This means that the range of management options to be considered and executed must continually alter in response to these eventualities. In reality it seldom does for the fisheries known to us throughout the world. Rather, a very limited range of options - and often only an unimaginative set of these - is applied over and over without due regard to the unique characteristics of the fisheries environment as it evolves in space and time. If a given action fails to attain the outcomes expected for it, the normal response is more often one of applying the action with greater force in subsequent years rather than trying to figure out the underlying reasons for failure and searching for suitable, creative alternatives to be applied in coming years. For example, investment decisions have profound impacts on individual and world-wide fisheries. Rather than continuing to blame bankers for allowing over-capitlization, with consequent degradation of individual fisheries, a system view would suggest that the problem be attacked through the use of control of access, so that some other institution has control on the investment. The impacts of overfishing and "bad years" on localized fisheries are well known; however no institution exists that would indemnify fishermen in localized disaster areas, to support non-fishing for short periods of time while stocks are replenished or to encourage retraining and relocation in those cases where a stock has been destroyed. A system view would rapidly lead to this kind of recommendation and would, as a result, do much to alleviate a common and constant management problem.

6. Conclusions

6.1 The present state of fishery management

The present state of exploitation of the world fish stocks is such that it is unreasonable to expect much increase in the total catch of the familiar stocks, and the continued productivity of these stocks is threatened by the existence of a world fleet that is probably, taken as a whole, well in excess of what is desirable on economic grounds. Nevertheless, there are enormous pressures - from individual fishermen, companies, shipbuilders, national governments and international funding agencies - to increase still further the world's aggregate fishing capacity. The potential benefits from improved fishery management are vast. They include maintenance of the present yields; reduction in the excessive economic costs, and social conflicts, involved in excess effort, and possibilities for improved use of the product.

The establishment of exclusive economic zones provides the opportunities to implement better management, but in itself does little to ensure that the opportunity is grasped. The matter is urgent. With every year that passes the growth in fishing capacity adds to the strain on the resources, and requires a greater re-adjustment to reach a rational level. Each year's delay makes the implementation of effective management more difficult, and increases the economic and social disruption.

Implementation of management usually requires taking difficult political decisions, e.g., to limit access or to reduce fishing or at least the growth of fishing, by one sector in order to protect the interest of another group. It is therefore important that the special problems of fisheries (open access, etc.) are appreciated by the most senior levels in government, as well as in the other groups of the public directly or indirectly concerned with decisions affecting the management of fisheries.

The Working Party therefore suggests:

(i) that FAO take appropriate action to make the top levels in governments aware of fishery management problems;

(ii) that action is taken to bring the problems to a wider public, including the production of a forceful documentary film.

6.2 Changing the decision environment

Better management will require a change in the environment in which management decisions are made, and a greater awareness of the processes that are involved in management. Three types of action were identified that could help - meetings; regional collaboration; and evaluation of the success of existing management schemes.

A world-wide meeting could be very effective in drawing the attention of influential people to management problems, and also in providing a forum for technical discussions, but the two functions must not be confused. The Working Party noted that FAO was considering the hold of a conference on fishery management, possibly in 1982. With careful planning this conference could serve either, or both purposes, but if it were to be used to draw attention to problems it would be essential to ensure the participation of the most senior people. The run-up to such a major occasion could also include the holding of preparatory meetings to consider particular problems, or to address particular audiences.

International collaboration through regional bodies has in the past been very effective in a number of ways, particularly in producing scientific advice concerning the management of stocks exploited by several countries. The changes in the legal regime of the sea has altered fundamentally the role of regional fisheries bodies. Most management decisions will be made by individual countries in respect of the fisheries in their own EEZ. When stocks are shared, the necessary decisions could be reached by the two or three countries concerned through direct consultations, or through a regional body. A regional

body can also be useful as a forum for general discussions on all aspects of management, including scientific and technical matters, and method of surveillance and enforcement. These are likely to be particularly useful for small countries unable to provide within their own resources the critical mass necessary for effective discussion.

The Working Party believes that the direct and indirect management roles for regional bodies under the new regime are not clearly defined or understood. A study by FAO of this topic would be most useful, and could distinguish the role of regional bodies in respect of:

(a) stocks occurring wholly or in part outside national jurisdiction;
(b) shared stocks, and
(c) stocks under a single jurisdiction.

Such a study should distinguish the possible different roles of a regional body at different stages in the management process (data, information, decision, etc.).

The case for better management would be easier to present if there were clear examples of ideal management, i.e., where no improvement in the system could be achieved. Examples can readily be given, e.g., West Australia rock lobster, where management has been successful in the sense of making the situation (as measured by one or more of total catch, gross earnings, etc.) better than it would be in the absence of any action. It is less easy to determine how these fisheries perform in comparison with what might have been achieved. A major obstacle is the absence of any established methodology of how to evaluate the performance of a management system, or what the theoretical optimum management would be. It would be useful if FAO could arrange for a study into the methodology of evaluation of management system performance.

6.3 Components of the management system

Objectives

Objectives must be clearly determined, and the possible conflicts between objectives identified, and dealt with. Maintenance of the stock at a satisfactory level is a necessary part of the action to achieve most objectives, but is seldom sufficient in itself.

Boundaries

A proper choice of the boundaries of the problem is vital. Many failures in the management of fisheries can be ascribed to the use of too narrow boundaries, but wide boundaries make analysis difficult. There is little available guidance in the fisheries literature on how to choose appropriate boundaries. A study on this subject would be useful, and might well take account of the existing theory on the efficiency of sub-assembly.

Data

Suggestions for improving data availability are given in Appendix 6. These should be acted upon.

Information

Models are an important set of techniques for transforming data into usable information. They should be used not only in prediction (e.g., of the effect of proposed management measures) but also in providing insight into problems and in planning and evaluating data acquisition programmes. It is therefore desirable to use appropriate models, even in the early stages of developing a fishery management system.

Models of individual elements (e.g., of the behaviour of exploited fish stocks) are in general satisfactory. Where they are not, e.g., concerning the biological interactions between different species, the difficulties are of fundamental scientific uncertainty, rather than in model-building. The Working Party therefore believes that additional emphasis was not needed at this time on the construction of better sub-system models. In other words the failure of the modelling art to exhibit material improvement lies in a limited understanding of some of the basic biological phenomena that underlie the processes that are of concern to fishery managers. There is a need for concentration of research efforts on some of the problems already identified. Recruitment processes and species interactions are the most important examples. The Working Party re-asserted the proposal in the interim report (Section 6.3) that an analysis could usefully be made of the degree to which research is focussed on important issues, and how these issues could be tackled.

At the higher level, there is a lack of models of the behaviour of management systems as a whole. For example, though the existence of technological and biological interactions between fisheries on different species is well acknowledged, there are no generally used models of the behaviour of fisheries based on several species that can be used to guide management. In their absence decisions tend often to be taken under the implicit assumption that each species lives in isolation. Such models should be developed.

Formulation of Action

Though maintenance of fish stocks is essential, other aspects should not be neglected. In particular the impact of actions on the economic efficiency of the fishery should always be examined. It is easy for managers to become too regulation-minded, but they should not be concerned only with imposing restrictions. Also, for any fishery, the possibility of unexpected events should be taken into consideration. If sudden changes in stock abundance (resulting for example from environmental changes) are thought possible, management should be prepared to react quickly and decisively to such changes. The procedures to be followed should be set up in advance, and the state of the fishery should be closely monitored for impending signs of change.

Execution

The execution of management policies and especially the introduction of restrictive measures should be preceded by consultation with fishermen and any others affected so that they are fully informed of the purposes of the measures. Fishery extension officers, where they exist, can have an important role. Early attention should be given to the methods of enforcement, including their costs, and the nature of the penalties.

Evaluation

A weakness of most fishery management is in evaluation. What is done is usually of individual elements of the system, e.g., of biological research. There is a great need within most countries for improvement in the regular evaluation of the impact of the management system as a whole on the national fisheries. This will usually be most effective if done by those not directly concerned with operating the system. The most difficult aspect of an evaluation of the system is the determination of its impact, i.e., what difference is being made to the success of national fisheries. In view of the external factors that affect fisheries, e.g., natural fluctuations in stocks, this is very difficult to do. It would be useful if FAO arranged for a study of how such an impact evaluation of fishery management systems might be carried out.

The important evaluations must be carried out nationally; and examine national systems. At the same time it is useful for countries individually to know in general terms how fishery management systems are performing in the world as a whole, i.e., to have something that is rather closer to an inventory of fishery management practices. The FAO Committee on Fisheries has in the past reviewed the state of world fisheries, and also the activities

of regional fishery bodies. It would be useful if these were continued regularly, especially if the former is widened to include more on the success of management, rather than concentrating solely on the state of the resources, and if both examined, how well the systems were working, particularly drawing attention to the successes and the reasons for them.

6.4 Systems Problems

Training

The greatest obstacle to better management is, in most countries, the shortage of trained people. Existing training,(e.g., FAO's programme of training courses and the production of manuals) in individual techniques relevant to fishery management (e.g., collection of statistics, stock assessment, etc.) needs to be strengthened. A particularly urgent need is for training of people in fishery management as a profession in its own right. The proposal for an Institute of Fishery Management prepared by Professor Brewer at the request of the Working Party in its interim report (Section 6.13) is given in Appendix 2. The Working Party strongly endorses this proposal, and stresses the importance of FAO giving urgent attention to finding ways for its practical implementation. Apart from training, the existence of such an institute could lead to the necessary improvement in the status of fishery managers as professionals, and to attracting and keeping high quality staff. Progress on management has often been retarded by very rapid changes in the government officials responsible for fisheries at the top levels. It would be important for such an institute to collaborate closely with existing regional arrangements.

Structure and Communications

These are linked. While many decisions affecting fisheries are taken within governments (e.g., on tax policies, investment planning, etc.) they are not always brought together to provide a coherent and consistent approach. This needs good communication between disciplines, but these often are not satisfactory. The failure of communications, e.g., between resource scientists and investment planners, has been in part due to the forms of communications (economists do not understand all of what biologists are saying), but even more to the weaknesses or even absence, of channels of communication (investors are not aware that biologists have anything relevent to say). It is therefore important for countries to examine the structure of their administrations to ensure that there is adequate communication between all those whose decisions can affect fisheries. In particular decisions tend to be taken in response to initiatives from one or other technical group. It is important that somewhere in the government structure there should be one person or unit responsible for taking a broad view of the whole fishery.

In view of the influence that investment decisions have on fisheries, and the fact that often too narrow a view of the effect of investments leads easily to excess investment and over-capacity, investment planners must cooperate closely with those looking at the resources. For example, it might be a condition of any government approval of investment that an analysis has been done of the impact on the resources and on existing fisheries, and that the overall impact of the proposed investment is favourable to the national fisheries as a whole.

The same is true on the international scale. The increased international attention now being given to assisting the poorer sections of the community within countries is attracting large-scale investment into the development of artisanal fisheries. Unless these investments are matched to the resources and their current state of exploitation, the impact on the fisheries as a whole could be disastrous, even in cases when measured by narrow criteria (e.g., the internal rate of return) the investments appear successful. The Working Party urges FAO to take action to ensure that decisions on fishery investment, especially in the artisanal sector, did take into account the impact on resources and on the catch rates of existing fisheries. This might be done partly through high-level seminars and workshops, attended by bankers, fishery managers and resource specialists.

The Working Party also endorses the proposal in its interim report (Section 6.11) of a critical review of the investment process, and of the extent to which consideration of the resources, and of fishery management problems were taken into account when making investment decisions.

The Working Party also points out the necessity for FAO to be prepared to give advice, as requested, to countries in the difficult work of arranging their internal structure and communications in such a way that the right advice and information is available to the right people when decisions, whether on investment or on regulations, are being taken.

APPENDIX 1

A COMPARISON OF LIMITED ENTRY FISHERIES MANAGEMENT SCHEMES [1/]

by

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1/ This paper was conceived at a limited entry conference in the summer of 1978 at the University of Washington. The conference also provided an important focus for assembly of background information on limited entry schemes. Subsequent to the conference I was asked to provide peer review for some of the papers dealing with specific limited entry or exclusive rights management schemes. I suggested to the various authors that a direct comparison on an issue-by-issue basis of the various schemes would perhaps be more useful than a series of advocatory papers on each of the schemes. This is what I attempt to do in this paper. Because the final proceedings of the conference are not yet completed I do not know if any of the authors actually took my suggestions. If so, I will welcome their points of view.

I would like to dedicate this paper to the memory of the conference organizer, Prof. Donald McKernan. Research funding was provided by the Food and Agriculture Organization of the United Nations. I would like to acknowledge the useful comments provided by Colin Clark, but the usual disclaimer applies.

SECTION 1

Introduction

The purpose of this paper is to compare and contrast four different types of limited entry, (sometimes called exclusive rights) management schemes on the basis of specified criteria. A definition of limited entry management schemes is provided below. The analysis, for the most part, will involve qualitative comparisons of the four schemes. Actual or hypothetical examples will be used where possible. It is my opinion that the basic conclusions derived below would follow using a more theoretical model with formal rigorous analysis. (Such an analysis, which came to my attention after the basic work for this paper was completed is Clark (1979)). I have taken this qualitative approach because the analysis will be more readily understandable to non-economists. Due to the vast literature on the subject (Gordon, 1954; Scott, 1955; Christy and Scott, 1965, and Anderson, 1977) I will not present an argument for the necessity of regulation in a common property fishery. Without regulation, however, resources will be suboptimally allocated to the harvest of fish such that the total value of goods and services produced in the economy will be lower than it need be. In addition, the fish stock can be unduly stressed. Regulation can be justified if it can solve the above problems.

I have chosen to limit my discussion of fisheries regulation to limited entry management schemes because they are the only ones that can offer hope of lasting improvement in the economic performance of the fishing industry. Traditional regulatory devices such as time closures, quotas, area closures, gear restrictions, etc. can achieve a reduction in fishing mortality and hence reduce or eliminate stress on the stock of fish. However they will, directly or indirectly, lead to an increase in the cost of harvesting fish thus largely eliminating the economic benefits of regulation. Therefore if one is concerned with the economic efficiency of harvest as well as the biological stability of the stock, the range of choice in fundamental management options is narrowed considerably. However, the traditional regulatory devices will, in many cases, be necessary components of a proper management procedure. This point is discussed in more detail below.

With respect to the above, Pearse (1978) has written:

"In short, none of these common regulatory techniques can mitigate the underlying long-run tendencies toward inefficiency in fishing through excessive use of labour and capital; generally, they aggravate the problem. In order to ensure that the potential economic gains from exploiting fish resources will be generated and realized, measures must be found to overcome the fundamental problem of expansion beyond the capacity necessary to efficiently harvest the available catch. This implies restricting the fleet to the capacity that can be fully utilized, and ensuring that the structure of the fleet and its fishing methods are efficiently designed."

In a similar vein, Crutchfield (1979) says:

"But cost and net economic benefit <u>are</u> important, and it is abundantly clear, from theory and experience, that no management program that does not include control over inputs to fishing (or induce fishermen to do so) can offer much lasting improvement in economic performance over open access. Thus any discussion of the economic aspects of rationalization must focus on means of reducing total inputs for any given catch level and on the extent to which least-cost combinations of inputs can be encouraged."

I have a dual reason for introducing these two quotes. First, they offer corroboration of my argument that traditional regulation devices cause economic inefficiencies. Second, they provide a basis for a definition of limited entry management schemes. It is interesting, for me at least, to note that despite all of the attention focussed on limited entry recently, it has not been formally defined. Based on the above, a general definition of a limited entry management scheme would be a fisheries regulation programme whose goal is to restrict the total inputs used in the fishery but which does not directly affect the efficiency of those inputs.

Summarizing the above, this paper will start with the premises that fisheries regulation is necessary because of the common property nature of living marine resources and that limited entry programmes will be necessary in order to achieve economic efficiency in fisheries utilization. From that point of departure, the goal of the paper will be to compare and contrast various types of limited entry management.

The main achievement of the paper may be the provision of a frame of reference for comparison. Because of space and time constraints, it will be possible to compare only the main aspects of the four types of limited entry programmes and then only in fairly general terms. The basic conclusions derived using the analysis should be of general use, but specific institutions, cultural influences, and biological peculiarities of particular stocks in different situations may necessitate modifications of the general results provided here before they will be directly useful in practical plan development. However, even if the only achievement of the paper is the presentation of the framework of comparison, and a demonstration of how it can be used, that should be a useful contribution to the literature.

The remainder of the paper will proceed as follows. Section 2 will provide a very brief description of four basic types of limited entry schemes. Section 3 will describe the basic framework in which the comparison will take place. This framework consists of a set of problem areas that must be addressed to one degree or another in the implementation and operation of any type of fishery management scheme. Section 4 will amplify the discussion of the four types of limited entry in the context of the problem areas described in the framework for analysis. Its purpose will be to describe how the various schemes can be modified to address the various problem areas. The goal will be to describe the best possible adaptation of each of the schemes so that meaningful comparisons can be made. The final objective will be to specify under which conditions each of the schemes will be most useful. A summary and some basic conclusions will be found in Section 5.

SECTION 2

General Classification of Limited Entry Management Schemes

When regulating an economic activity there are two basic contact points: prices and quantity (see Weitzman, 1974). The price versus quantity dichotomy can be analysed more clearly by directly considering inputs and outputs. That is, an economic activity can be regulated by affecting the price of the output or the inputs, or alternatively by regulating the quantity of outputs or inputs. With respect to fisheries, and considering only limited entry schemes, these types of regulations translate as in Figure 1. A price regulation on output would be a landing tax, while a price regulation on inputs would be an effort tax. Similarly the quantity control on output would be a fisherman quota (see Christy, 1973, 1975) and a quantity control on inputs would be an effort share programme or a licence programme.

Price	Output	Landings Tax	
	Input	Effort Tax	
Quantity	Output	Fisherman's Quota	
	Input	Effort Share	Licence

Figure 1

The landing tax programme would consist of a fee, either a percentage of price or an absolute amount, levied against the harvester as he lands his catch. An effort tax would consist of a fee levied based on days fished, tonnage, type of gear or some other proxy for fishing effort. A fisherman quota would consist of a specific allowable catch for each harvester that is allowed to operate. The allowable catch could be a fixed amount each year or a percentage of some total allowable yield. An effort share programme is similar to a fisherman's quota except that the right granted to individual harvesters is stated in terms of an allowable amount of effort per year rather than an amount of catch. That is, the person would be allowed to fish so many days per year with a specified type of gear, although perhaps with restrictions on time and area of fishing. Here again the fishing effort share may be a fixed amount each year or a specified part of some annually determined amount.

I have classified licensing schemes as a control on inputs. In its purest sense, the basic idea for a licensing programme is to determine the amount of effort that can harvest some predetermined allowable catch over the year and then to issue a fishing licence to an appropriate number of vessels, gear or fishermen such that that catch is obtained. However a more practical interpretation of existing licensing programmes would be that they are means to limit the fishing power in a fishery by limiting the allowable amount of one or more critical input. That is, only a certain amount of boats, men, units of gear, are licensed to fish.

With the exception of licensing programmes, the other four are identical in a certain, but limited, theoretical sense. If it is possible to specify the relationship between inputs and outputs, and outputs and prices, it really does not matter which one is actually regulated. A tax on effort can be readily transferred to a tax on landings and vice versa. Similarly a share of effort can be translated to a fisherman's quota. Of course in the real world the problem of specifying these relationships is very real. It is because of the difficulty of specifying the relationship between effort, catch, and prices, etc., that an analysis such as this is necessary. Though theoretically the same, each of these management schemes is, in practice, quite different both in implementation and operation. Just how different and in what particular ways is the subject of this paper.

The difficulty of specifying exactly what effort is in terms of days fished, gear, etc. and the absolute simplicity of specifying landings makes the landing tax and the fisherman's quota appear to be superior to an effort tax and an effort share programme respectively. While landing taxes appear at the surface to be so far superior to effort taxes that the latter should not be considered, fishermen quotas are not that superior to effort share programmes. Accordingly of the four basic types listed in Figure 1, only landing taxes, fisherman's quotas, and effort shares will be discussed. Licence programmes will be treated separately in detail because of their current popularity and their differences from effort share programmes.

All of these may be called limited entry programmes because their aim is to reduce the total inputs in a fishery without directly affecting efficiency. As will be pointed out below, their ability to achieve this aim varies considerably, however. All except taxes may be called exclusive rights management schemes because the restriction on the amount of inputs is obtained by granting property rights or a quasi-property rights in the fish stock.

SECTION 3

A Framework for Comparison of Fisheries Management Schemes

Whether a fishery management scheme can be judged a success or a failure depends upon a great many things. The framework presented below is a suggested way of organizing the various judgement areas. Four general problem areas are listed, each of which contains a

series of topics. These are schematically displayed in Figure 2. It is hoped that the framework is all inclusive, although other writers may have organized it differently. The four main problem areas are: management operations, socio-economic effects, biological effectiveness, and economic efficiency. Each of these and their corresponding subtopics will be discussed below.

Management Operations	Socio-economic Effects
1. Implementation	6. Distribution
2. Flexibility	7. General Effects on Prices and Employment
3. Other Types of Regulation	
4. Intrafishery Conflicts	
5. Multi-purpose fleet problems	
Biological Effectiveness	**Economic Efficiency**
8. Capability of Achieving Goals	10. Vessel and Fleet Operating Efficiency
9. Interdependent Species	11. Technological Advance
	12. Research and Regulation Costs
	13. Freedom on Individual Participants

Figure 2. Problem Areas for Comparing Management Schemes

A. Management Operations

1. Implementation. An important criterion for judging the acceptability of a management scheme is the ease with which it can be implemented. Several factors are important here. First, the more complex or detailed the plan, the more difficult it will be to set up an institution to administer it. Secondly, the more it differs from current operations, or the more the institution necessary to manage it is different, the more difficult it will be to implement. If there are no precedents for the policy or its operational arm, those who feel their interests are not protected may be more inclined to resort to law suits or other procedural steps to retard implementation. Also, it will be more difficult to set up an organization that is different from anything that exists, because of the simple lack of acceptable models.

Another important part of implementation is political and social acceptability. It will be quite difficult to obtain legislative approval or, achieving that, to administrate even a very simple plan that is violently opposed by many, or powerful, sectors of the fishing community. The level of acceptability depends on how each of the problem areas, including implementation, are addressed, and so acceptability will not be treated separately.

In short, the more complex, radical, or unpopular a management scheme is, the more difficult it will be, all else equal, to implement.

2. Flexibility. In order for a fisheries management plan to be a success it must have some inherent flexibility. This flexibility must take two forms. First, there must be built-in ways to take drastic steps to deal with emergency situations in the environment. Fluctuations in natural abundance, seasonal availability, etc. are inherent characteristics of fishery resources and yet measurement and forecasting capabilities with respect to them are very limited. Therefore, there must be power to halt fishing by area,

time, gear, or species if the situation warrants. Similarly, there are seasonal stochastic effects that can change the productivity of the stock from year to year. Therefore it will be necessary to have the power to make broad changes in the general fishing capacity over time as well as specific drastic cuts within a season.

There must also be flexibility with respect to the ability to change the basic nature of the programme. This is a very delicate situation however. On the one hand, even if there is ample time for public discussion, and input it is unlikely that the first version of a plan will function perfectly. Only time and actual operation will allow weaknesses to become evident. Therefore, there must be procedures for changing the plan to overcome weaknesses. On the other hand, a plan that is very simple to change will become easy prey to political pressure. A programme that is the result of many ad hoc changes instituted by various pressure groups without consideration for the entire makeup of the plan itself will, more than likely, be less than satisfactory. In addition the fishing community's faith and acceptance of a plan that is changed often will likely be quite low.

3. Other types of regulation. Another criterion for judging the overall usefulness of the fishery management scheme is the need for, and compatibility with, other types of regulation. In some sense this is related to the previous topic of flexibility. In many instances due to the emergency or stochastic situations discussed above, or due to the nature of the management scheme and of the particular fishery to which it is applied, other types of regulation will be necessary. Drastic declines in recruitment may call for closed seasons. Similarly, a fisherman's quota may not give adequate protection to a nursery area and so a closed area may be necessary. Obviously the greater the number of these extra regulations needed, the more difficult it will be to implement and operate the particular management scheme. On the other hand, the greater the adaptability of the programme to other regulatory devices, the easier it will be to implement and operate.

4. Intra-fishery conflicts. In almost every fishery there will be some internal conflict, i.e., offshore vs. inshore fishermen, recreational vs. commercial fishermen, part-time vs. full-time fishermen, artisanal vs. industrial fishermen, and competition between users of vessels of different types, sizes and gears. At the heart of most of these conflicts is the distributional question of who will reap the gains of the fishery, with or without management. In this sense, this problem area is closely related to distribution which is item number 6 below. The ease with which solutions to these problems, if they exist, can be made a part of the management plan is certainly an important criterion for judgement.

5. Multi-purpose fleet problems. Quite often a vessel can operate in completely different fisheries at different times of the year. This may or may not involve a change in the gear structure of the vessel. The boat may trawl for a certain species in one area in the early part in the season and then use another type of gear for another type of fish later in the season. It is especially important with respect to limited entry programmes that this problem be addressed directly, especially if there are individual limited entry schemes for different species. It would be economically irrational to have a duplication of fleets and there should be some rational procedure to allow those vessels capable of switching from one fishery to another to do so.

From the fisherman's point of view, it makes sense to use his vessel during the entire year as long as he is covering his variable costs during each part of the year. From the society's point of view, there is obvious waste if two boats must be built to do the work that could be done by one. Further, it may be that a specific species that is only available for a short time each year is not capable of supporting the full cost of a fishing fleet. However, it may be easily capable of covering variable costs for an existing fleet that is idle or used in a less productive fishery during that period. See Huppertt (1979) and Anderson (1979). Therefore the ease with which this switching behaviour is permitted is an important thing to consider when comparing management schemes.

B. Socio-economic Effects

6. Distribution. Although biological effectiveness and the ability to achieve economic efficiency are important criteria for judging and selecting fisheries management schemes, in most instances the distribution of the gains and losses per se is the most dominant criterion. Legislatures, decision makers and the participants themselves are vitally interested in the distribution aspects of a programme. Even if a particular programme can succeed biologically or achieve economic rationality, if the distribution effects are contrary to accepted norms, it will not be accepted. Therefore the actual distribution characteristics of a programme and the ease with which they can be modified must also be considered.

7. General effects on prices and employment. Although perhaps not as important as distribution, its effects on prices, employment and other socio-economic variables are important characteristics of a management scheme. Employment in related industries (boat building, fish processing and marketing), export levels, preservation of traditional fishing communities, general price level to consumers, etc., are matters of concern to policy-makers. In judging a management scheme, it is necessary to determine if its results will be counter-productive to other government policies concerning these parameters. Obviously, all else equal, those that would generate higher prices or higher costs would be deemed less satisfactory than those that did the opposite. For purposes of this paper, it will only be possible to sketch out some general effects of each of the schemes. The specific effects of a certain scheme on a particular fishery can only be determined by a detailed analysis.

C. Biological Effectiveness

8. Capability of achieving biological goals. This criterion is self-explanatory, but one point can be made. Obviously if a regime cannot satisfy biological goals and therefore puts the stocks in danger, it should not be considered. However there are ranges of acceptability. Some regimes will achieve a biological goal but only if there is constant monitoring and many side regulations. Others can achieve a biological goal by the very nature of the regime itself. Obviously, all else equal, the latter would be a preferred management programme.

9. Interdependent species. The interdependence of species can be biological or technological (see Anderson, 1975). Biological interdependence occurs when the size of one stock directly or indirectly affects the size of another through predator-prey relationships or through competition for some limited aspect of the environment. Technological interdependence occurs when the harvest of one stock results in the harvest of another. When these interdependencies exist, it is better if the management for the stocks involved can be at least coordinated, but preferably, combined. This will allow the management authority to directly consider the effects of a particular management regime on both of the stocks. However, even when combined management is possible, the interdependence of the species makes the task much more difficult than in a single independent fishery. The most obvious problem is how to restrict the harvest of one of several technologically related species. In fisheries where by-catches inadvertently occur, properly enforced prohibitions or restrictions on one of the species will cause fishermen to either stop fishing or to discard the prohibited species at sea when they would otherwise have kept it. The latter will cause a decrease in landings but not mortality of the prohibited species. Since, to one degree or another, interdependencies occur in almost all commercial fisheries, one vital criterion for judging management schemes is how well they can adapt to combined management or address the interdependency issues.

D. Economic Efficiency

10. Vessel and fleet operating efficiency. Economic efficiency of harvest is an important criterion for fisheries management. Indeed one of the premises stated above is that the main justifications for considering limited entry management schemes is that

they are the only ones which are able to encourage economic efficiency in the long run. Obviously different types of limited entry schemes will have different effects on economic efficiency especially when all of the side regulations are considered. As stated in the Pearse and Crutchfield quotes above, the goal of economic efficiency is to harvest at the optimal rate, defined as that point where the value of the last unit of harvest is equal to the marginal cost of obtaining it (see Anderson, 1977, p.34) using that size of fleet and individual vessel operating level where the cost of the optimal level of harvest is minimized. Obtaining this goal is quite complicated due to the multiplicity of elements that must be considered (see Crutchfield, 1979 and Scott, 1979). For example, in addition to the problem of biological and technological interdependencies discussed above, there are also problems of the proper age composition of catch, and the proper areal and temporal distribution of effort (both within a season and over a period of years). Both of these are important because by varying the age composition of catch or the time and spatial characteristics of harvest it is possible to affect the value of final harvest and the cost of fishing activity. Therefore in order to ensure that the net value of harvest is maximized it will be necessary to consider these elements. The above point should be kept in perspective, however. While it is true that these complicating issues are relevant, management complexity to account for them should be related to the net benefits that are achievable taking into account the costs of regulation (see item 12 below).

11. Technological advance. Another important part of economic efficiency is the encouragement that is given to research and development and also to the rate at which technological advances are introduced. Open-access can sometimes cause technological advances to be introduced too rapidly (see Scott, 1962). The competition for the unowned stock of fish will cause vessel owners to introduce new technologies as soon as they are developed in order to remain viable, rather than let existing equipment depreciate in an optimal way. If private ownership existed, new technologies would not be introduced unless the variable costs of existing equipment, whose fixed costs have already been paid, are higher than the total costs of the new technology.

Also, various regulation schemes can prohibit efficiency and, just as important, discourage research. Why try to find new fishing techniques when regulators will just ban their use? In order for a fishery to remain economically efficient over time it is important that adequate effort be given to improving the manner in which the fishery is exploited and that new methods are introduced in an optimal manner. Therefore it is important that a management regime directly consider these issues.

12. Research and regulation costs. The only economic justification for fisheries management is that the value of the benefits will be greater than the costs of management. That is, under open access the stock will be at a certain level and the net gain to the economy and to individuals in it will be at a certain size. The justification for management is that it can improve these. That is, the stock will be in a better health and there will be a net increase in the value of goods and services produced from the economy. Obviously the amount of research, regulation, and enforcement costs necessary to implement a plan will have a great effect on the net benefits of the management scheme. Specifically, the value of goods and services lost elsewhere in the economy due to the transfer of resources to the regulation process must be less than the increase in the value of goods and services that result from the regulation. Otherwise there will be no economic efficiency justification for management. All else equal those schemes that require a smaller amount of biological and economic information to implement and are less expensive to enforce will be superior.

13. Freedom of individual participants. The degree of freedom for individual participants is an important criteria for several reasons. First, in many cultures this is a valued ideal in itself. Second, greater freedom of individual operations usually means that less direct control will be necessary thus lowering enforcement costs. Finally, to the extent that fishermen can have free choice in the selection of fishing methods, fishing gear, size of boat, etc., there will be a tendency toward minimization of fishing costs. The individual fisherman wants to maximize his profits, and he can do this by

producing any given level of fishing effort at the lowest possible cost. If a management scheme can do away with the open access problem and yet still allow a range of individual freedom for the entrepreneur, costs should be lower than they would be with constraints on freedom. Experience has shown that when government officials decide the size of the boat, time of fishing, type of gear used, etc. it is very difficult to achieve the input combination which minimizes costs.

SECTION 4

The Framework Applied to the Various Types of Limited Entry Programmes

A. Tax Schemes

1. Implementation. Implementing a tax scheme can be difficult or easy depending upon which stage is considered the beginning. In many instances, getting appropriate legislative approval for a tax scheme will be quite difficult. Most legislatures are very wary of giving the power to tax to a non-legislative body. And, even if they were so inclined, pressure groups from the fishing industry would most likely lobby against such a proposal. No industry likes to be regulated, and taxation is probably the least popular form of regulation. Regulation will be accepted by the fishing industry if it can be shown to be beneficial to them. A properly instituted tax programme would be beneficial to society as a whole, but it would not necessarily help individual fishermen except to the extent that biological fluctuations decrease as a result of decreases in fishing. Accordingly, the industry cannot be expected to support such programmes. In summary, the desire of legislatures to keep a close watch on taxing power, and the opposition of the fishing industry to taxes, makes the prospects of legislative approval quite dim.

However, if a tax scheme is approved the basic implementation will be relatively easy, especially when compared to other limited entry programmes. Taxes are a way of life in almost every country. There are existing government agencies with standard procedures for collecting taxes. Sales taxes and taxes on the production of cigarettes and liquor certainly are comparable to a tax on fish landing. The latter are especially good models for taxes in the processing stage. A proper procedure would involve setting up reasonable methods to ensure that all processed fish can be accounted for so that the appropriate tax can be collected. To the extent that fishermen work with processors it will be a relatively simple matter to identify when fishing has taken place. The surf clam fishery in the mid-Atlantic United States is a good example. If participants want to continue in the fishery they will have to pay the tax. At the other extreme is a fishery with many landing ports and a widely dispersed fresh market. Here it would be difficult to ensure that the proper taxes could be collected (see item 3 below).

2. Flexibility. Tax schemes rate relatively low in the area of flexibility. There are many lag periods involved in a tax structure. There is the lag between the identification of a problem and the actual change in the tax structures. There is a lag between the change in the tax and the change in behaviour of the fishing units and the lag between the change in behaviour of the fishing unit and the effect on the economics and biology of the fishery. Therefore it would almost certainly be the case that a separate set of controls, such as closed seasons and closed areas, will be necessary for emergency situations. As far as stochastic year-to-year effects are concerned, taxes can possibly work, but they would have limitations here as well. The explanation of the lack of flexibility has to do with the difference between fixed costs and variable costs in fishing operations. As long as a vessel is covering its variable costs it will continue to fish. In many cases, variable costs are a low percentage of fishing costs, therefore tax rates would have to be quite substantial in order to force a fisherman to stop fishing, especially in the short run.

3. Other types of regulation. Because of their lack of flexibility and also because of potential problems in meeting biological goals (see item 8), taxes would certainly require other types of complementary regulations in order to become effective. The best

way to minimize these difficulties would be to specify in advance that taxes will not be the only form of regulation, but, when necessary, other controls will be used. In addition, the exact nature of such controls, and the conditions for their emergency implementation should be clearly delineated. For instance, if catch, even in the presence of the landings tax, reaches a level that is say 90% of a biologically safe catch according to accepted criteria, then in addition to the tax, vessel quotas, weekly catch limits or some other catch reduction programme will be instituted for the last 10% of harvest. When the biological limit is reached the fishery will be closed for the remainder of the year. The purpose of the separate regulations during the harvest of the last 10% is to allow for careful monitoring of the harvest as the critical level is approached. The above is used as an example only. Whether the adjustment period is needed, and exactly how to use one if it is needed, will depend upon the exact nature of the particular fishery being managed.

It is important to remeber, however, that these additional regulations should be used for emergency purposes only. As stated in the introduction, these regulations will always lead to economic wastes. They can be useful as short-term steps to handle specific problems which will remain even in the presence of a limited entry programme, but they should not be used as full-time management measures if economic efficiency is a goal of management. This is why it is important to have the conditions when the separate regulations can be used stipulated in advance. The conditions should be such that emergencies can be easily handled but that improper use of the other regulations are minimized.

Another problem with taxes is that if there is an extensive fresh market for the particular species involved, enforcement can be difficult. It is not unreasonable to expect fishermen to land their catch of valuable species in the dead of night at obscure points and ship direct to consumer outlets thus avoiding paying the tax. This will necessitate high enforcement costs or perhaps systems to collect taxes at the point of final sale.

4. Intrafishery conflicts. The effects of a tax programme on intrafishery conflicts depends, of course, upon the exact nature of the scheme. If there is a unified tax structure that applies to all landings, then it might appear that a tax scheme is neutral since it affects everyone the same. This may not be true however. Because of different comparative advantages in production, a uniform tax structure can affect the profitability of different vessels and gear types differently. It is most likely that certain segments of the fishery will be more able to bear the tax burden. From an economic efficiency point of view, this is good because the ones that cannot pay the tax will be the ones who have higher real costs of fishing. Therefore those that remain will be the most efficient fishing units. The purpose of limited entry programmes is to restrict inputs used. It is by forcing some units out of the fishery that this restriction occurs. Conflicts are bound to occur as units are forced out of the fishery, however. A proper tax scheme will ensure the economic efficiency of the remaining fleet, but it may not solve the problem of who remains in the fishery in a manner that is acceptable according to income distribution or cultural criteria.

If it is desired to give preference to special parts of the fleet, it is possible to devise a scheme with different rates according to gear, etc., but implementation and enforcement may be difficult. In addition, a tax scheme which assesses a different level of tax to the same type of catch in the same season to different types of gear may be illegal. It most likely would be unconstitutional in the United States.

5. Multipurpose fleet problems. One advantage of a tax scheme is its ability to allow for optimal multipurpose fleet behaviour. As long as a boat is geared to catch fish in different fisheries and is willing to pay the taxes involved in each, it would be allowed to do so. This way a boat would not be exclusively tied to a fishery. Each individual vessel operator could plan a yearly harvesting schedule taking into account relative prices, taxes, fishing costs, and stock abundancies. If the tax rates are set at the proper level there will be an optimal sized total fleet and its allocation of effort to the individual fisheries will be optimal as well (McConnell and Norton, 1978).

This, of course, assumes that all fisheries have a tax scheme or another compatible limited entry scheme. Problems will arise if one fishery has a tax scheme and the others are regulated in a non-compatible manner.

6. Distribution. Not only does a proper tax scheme achieve an economically efficient harvest, but it also generates income for the public coffer. That is, the rents from the fishery will accrue to the general population. Whether this is proper is a matter of opinion. Several items are important here, however. One is that the income received by the government becomes a natural source of funds for fisheries biological research and enforcement costs.

As was mentioned earlier, one of the problems of implementing a tax scheme is getting it passed by a legislature. If a fishing industry has any lobbying power at all, it will certainly lobby hard against a tax scheme on the grounds of distributional effects. Although segments of the fishery may be affected differently, in general the profit making ability of each vessel will go down in the presence of a tax. Indeed in the most simple cases, an individual operator in a fishery that is rationalized by means of a tax will be no better off than he was under open access. The only difference will be that he will have fewer colleagues fishing with him. In some instances this is not politically acceptable (see Anderson, 1977, p.175). In order to entice a fishing industry to accept a tax scheme it may be necessary to compensate at least some of them with increased net revenues, but this will not be compatible with a tax structure that achieves strict economic efficiency unless some lump sum transfer programme can be developed.

7. General effects on prices and employment. The existence of a tax may lead some to predict that this form of limited entry will lead to higher prices for consumers than will other schemes. This is not the case. The burden of the tax will fall almost exclusively on the individual fisherman. A limited entry programme will increase or decrease price to consumers depending upon whether total catch goes up or down. Decreases in catch will lead to increases in fish prices (but there will still be gains to society as a whole as a result of the increased production made possible elsewhere in the economy (see Anderson, 1977, page 65)). On the other hand, increases in catch, which are sometimes possible even with reduction in the amount of effort because of resulting improved stock productivity, will lead to price decreases. The different limited entry programmes differ in the way that inputs are reduced, but to the degree that they are effective, they do not differ in the amount of final catch. Therefore, price to consumers will be the same regardless of the type of limited entry. With a tax, the difference between the real cost of fishing and the market price of fish is taken away by the government. Therefore the tax comes out of the price received by fishermen. It is not added to it. With other forms of limited entry, the fishermen can be allowed to keep the rent.

One advantage of taxes is that they will be less likely to result in monopolistic behaviour. It is possible that when granting fishermen's quotas or effort shares, that many of these property rights may end up under the control of single entities, thus allowing for the possibility of monopoly. Since there are no property rights per se in tax schemes, this accumulation of shares is not possible. However, the effects of a tax scheme may be to force a very large percentage of the operators out of a fishery because of their comparative economic disadvantage. This may lead to monopolistic behaviour as well. On the whole, however, this appears to be less of a problem than the potential accumulation of shares. Each case should be examined individually however.

8. Capability of achieving biological goals. As mentioned earlier, tax programmes may have problems achieving biological goals. This is because it is very difficult to ascertain exactly how fishermen will react to a particular tax in determing what level of effort they will produce. In addition it is hard to predict how much harvest will result from that amount of effort. The ability to achieve biological goals is especially limited during periods of rapid changes in the population size. However, the problem of obtaining a specified biological harvest in times of relative stability in the stocks, is no less real.

The tax will certainly encourage a reduction in fishing effort, especially in the long run, but exactly how much is very hard to predict. Therefore, it will be very difficult to determine a tax level that will achieve a specific amount of catch or fishing mortality. The best thing that can be done is to set a tax structure and then wait and see how effort and catch react. If things do not go as planned, the tax will have to be increased or decreased according to whether the actual harvest is above or below the desired amount. In some fisheries this procedure will be acceptable. However, when the population dynamics of the stock are highly volatile or there are critical stock recruitment conditions, other means of limiting entry will be preferable.

9. Interdependent species. Depending upon the technology of harvest, the skill of the captain, and the degree of separation of species, taxes can sometimes be very helpful in solving problems of interdependent species. If a tax is placed on a by-catch of a particular species, it will certainly motivate the captain to change his technology, his fishing area, etc., in such a way that the amount of this particular by-catch is reduced. On the other hand if by-catch is truly an incidental phenomena which the fishermen cannot control, a tax will have virtually no usefulness in solving the interdependent species problem. The fisherman will just be forced to pay a tax on this by-catch and it may force him to cease fishing or to discard fish at sea to avoid the payment of taxes. In the long run, however, taxes should encourage technological changes to reduce the by-catch.

10. Vessel and fleet operating efficiency. In the abstract a properly defined tax on output should promote fleet and vessel operating efficiency. Each vessel will be motivated to produce fishing effort as cheaply as possible and if the tax is set at the proper level, exit from the fishery will be encouraged until the maximum economic yield point is achieved (Anderson, 1977, p.174). The point about vessel operating efficiency probably holds true even in the most complicated of cases. However the point about fleet operating behaviour is less certain because of the problems of fixed and variable costs and difficulties in predicting how fishermen will react to changes in short run revenue. Nevertheless, barring the stochastic problems discussed above, taxes should achieve a reduction in the overall effort in the fishery, and an optimal tax should achieve an optimal reduction in fishing effort.

Certainly taxes are superior to fishermen's quotas, effort shares and licences with respect to one aspect of vessel behaviour where divisibility of effort is concerned. Licences, fishermen's quotas, and effort shares are lumpy propositions, and are difficult to split up into optimal sizes such that firms can operate at the minimum point of their average cost curves. With tax programmes, however, there are no constraints on the level of operations of fishermen other than the requirement to pay the tax. Therefore an economically efficient scale of plant can be achieved, or at least not hindered by the programme.

However to obtain efficiency between inputs and outputs at the fleet level and with respect to individual vessels, it is necessary to address some very complex issues. The age at harvest, the particular stock or species being exploited, and the place and time at which fishing takes place, all have an effect on costs, revenues, the quality of the harvest, and the size of the remaining stock. In addition, congestion between fishing vessels can affect the economic efficiency with which fish are produced. To the extent that these items are important an optimal regulation scheme should directly consider them. Carried to its logical extreme this means that the tax should be different to the degree that age, stock, species, place and time of harvest and congestion effects are felt. Obviously a tax structure that could accomplish this would be very difficult to devise and almost impossible to enforce. Once a fish is landed, it is very difficult to ascertain where or when it was caught. It is easy to determine species in most cases, but the cost of doing so would likely be very expensive. Fishermen can control for size, time and location of harvest. The problem is to set up tax structure that will motivate them to make the appropriate changes in an economically efficient way and at the same time will not be unduly expensive to implement. Although the complexity of a proper tax scheme is very real, perhaps a warning against the paralysis of perfection is in order here. While it may

not be possible to devise and implement a perfect tax structure, a simple tax plan concerned only with the very basics may go a long way in correcting for the economic inefficiency caused by common property.

11. Technological advance. Taxes are superior to licence schemes as far as technological change is concerned because there is no direct impetus to devise technologies that place an artificial premium on a limited input (see below). However they are probably not as good as fishermen's quotas or effort share programmes in encouraging the optimal rate of introducing technological advances. With tax programmes, entry is open to anyone who is willing to pay the tax. If innovations are discovered that will significantly reduce fishing costs there will be a pressure to institute them before existing equipment is properly amortized taking into account fixed and variable costs. If existing fishermen do not do so, new entrants will be motivated to do so. This will mean that the original fishermen will be at a disadvantage and may be forced from the fishery. Their profitability position will certainly be damaged. As will be discussed below, fishermen's quotas and effort share programmes will not encourage a too rapid rate of innovation because each fisherman will be guaranteed a portion of the catch or effort. They will be concerned with taking that catch or producing that effort at the lowest possible cost, where cost includes a proper analyses of fixed and variable costs.

This weakness in tax programmes theoretically can be overcome by proper adjustment of the tax structures taking into account the productivity of the new technology and the proper amortization period. This would probably be asking too much of a taxing system however.

12. Research and regulation costs. One apparent advantage of a tax programme is that it can be implemented completely on shore. At sea regulation is very expensive and its elimination should open the way for considerable savings in enforcement costs. But the degree to which onshore enforcement can be effective and inexpensive depends upon the exact nature of the fishery. For example, in the mid-Atlantic surf clam fishery in the United States all of the catch is processed by a limited number of processors, and a tax structure would be fairly simple to enforce. On the other hand there are fisheries with many processors and many options for fresh fish sale. In these instances enforcement could be quite expensive. Also in multispecies fisheries, it may be quite easy for the fisherman or processor to label one type of fish subject to a high tax as another type of fish subject to a lower tax. After the fish is processed it is sometimes very difficult to determine what kind of fish it was. In order to avoid such behaviour, very close inspection at the fish unloading centres will be necessary and this will be very expensive.

13. Freedom of individual participants. Tax schemes probably rate the highest as far as freedom of individual participants. Obviously there is some restriction on individual activities because they must pay the tax. But unless many types of other regulations are necessary, the fisherman can still fish with whatever type of gear he wants, when he wants, and using the exact input combinations he prefers. The implication of this for economic efficiency has been stressed above.

B. Fisherman's Quota Scheme

1. Implementation. The implementation of a fisherman's quota system, although simple in conception, is likely to be very complex in reality. The reason for this, of course, is the fact that it causes a rearrangement of property rights that affects the income and the way of life of individuals. When people feel they are being hurt, absolutely or even relatively, they are likely to complain and make their complaints heard by decision-makers and policy-makers.

Conceptually a fisherman's quota programme will divide the potential catch of the particular fishery, either into absolute amounts or percentage shares, and distribute them to individuals. The basic problem is to determine the nature of the shares, who should

receive them, and how many each should receive.

As a first step in determining the nature of the shares, it is crucial that citizens and the legislature accept the concept of a property right in fisheries. Although property rights to homes, business, land, etc. are an accepted and indeed a central part of most western economic systems, property rights in fisheries are viewed with much suspicion and distrust.

Although there is little real difference between a government leasing rights to harvest lumber in national forests and leasing or giving rights to harvest fish from a marine fishery, there definitely is a difference as far as acceptability is concerned. In order for a fisherman's quota system to work, the legislature and the appropriate management authority will have to accept the fact that a right to fish is not a civil liberty or an inherent natural right. It can also be a property right similar to others in that it is limited, transferable, carries privileges and responsibilities and is marketable. There are indications that governments are willing to make this shift; all around the world licensing programmes that limit the number of vessels have been adopted and in the Maine lobster fishery and mid-Atlantic surf clam fishery in the United States there has been serious discussion of actually granting individual fisherman's quotas.

Another important issue with fishermen's quotas is determining the exact nature of the right. Account must be taken of the inevitable year-to-year fluctuations in the biological and economical conditions in a fishery. This might be done by stating the individual quotas in terms of a percentage of annual total allowable catch. Another way would be to issue standard quotas and one or several classes of provisional quotas. The standard quota could be issued based on the minimal amount of harvest that would ever be allowed and they would apply every year. The provisional quotas would be for amounts in excess of the basic minimum and would be valid if certain special biological conditions existed, as determined by appropriate authorities, which indicated that the extra catches would be acceptable. The provisional quotas could be issued in a manner similar to standard quotas or they could be sold by the managing authority in the appropriate years (Clark, 1979a, and Moloney and Pearse, 1979). Regardless of how the individual quotas are determined, the formula for determining the annual total allowable catch should be specified as part of the limited entry scheme, and it should consider such things as economic efficiency of total fleet operation, the condition and size of the fish stock, etc.

In order to achieve economic efficiency a fisherman's quota should be a permanent property right that is freely transferable. The rights should be permanent so that the owners will be motivated to invest in proper harvesting equipment. If the rights are only granted for short periods of time, there will be a tendency to avoid long lasting capital equipment, even though it may be the most efficient in the long run. Obviously, the owners of the quotas will buy or rent that type of capital equipment that will be the least costly for his period of ownership. Due to the long amortization period of many of the large and efficient fishing vessels, they may not be suitable for the short-term owner.

Rights which are not permanent but are granted for the working life of the owner have their weaknesses as well, because they tend to discourage retirement. Such a stipulation may be easy to get around, but if it is enforced it could be very hard on the fisherman and have debilitory effects on the efficiency of harvest.

The rights should be transferable to facilitate production of effort at the lowest possible cost. Individuals who are very productive in producing fishing effort but who do not own fishermen's quotas will be motivated to purchase them. Similarly those owners who are less productive can make more money by renting or selling their rights. This way, regardless of the initial distribution, the rights will end up such that the fishing effort can be produced as efficiently as possible. It would also be useful if the rights were transferable in fairly small units. This would allow for easy entry to the fishery, and it would also allow individual operators to change their scale of operations so as to take advantage of economies of scale.

There are many ways to actually distribute fishermen's quotas. Schemes could be drawn up to allocate quotas according to history of participation, size of catch, dependence on the fishery, etc. It is also possible to use a lottery or an auction. The most acceptable would probably be the historical rights scheme. However, an auction scheme would more than likely result in the most efficient boats having the fishermen's quotas because they would be the ones able to afford the highest bid, however with complete transferability, efficiency in production could be expected (see above). In addition an auction scheme would allow rent from the fishery to go to the public coffers.

A final important issue related to implementation is the rate at which the total amount of fishing allowed is reduced from that which would be produced under an open access system. If the total effort allowed is reduced immediately to the long-term optimum there could be significant short-term difficulties for producers. There is a middle ground with an adjustment period which would allow for depreciation of old vessels and other adjustments to a lower level of effort.

2. Flexibility. If the fisherman's quota is devised such that it is a percentage of an allowable catch each year rather than absolute amount, there is flexibility built into the very nature of the programme. To the extent that stochastic variances in stock size as well as in other biological and economic parameters can be determined ahead of time the annual total allowable catch can be adjusted. Then, as part and parcel of the plan the annual allowable catch for each individual fisherman will be automatically adjusted as well.

Obviously all of the influences that affect the safe biological catch or the size of the economically efficient harvest cannot be known ahead of time. In some instances it may be necessary to change the size of the catch in the middle of the year. This may mean that all fishermen's quotas must be cut by an agreed amount or some other emergency measures will have to be taken. Serious problems can occur in these circumstances. For example, if some fishermen have already caught their quotas, while others are waiting to harvest later in the year, a mandatory reduction in the middle of the year will cause serious distribution problems, and if it happens frequently it will encourage all fishermen to land their quota as early as possible. This may lead to larger than optimum sized boats and artificial peak load harvesting. If this type of problem is expected to happen often, a programme of standard and provisional quotas may be advisable.

So while fishermen's quotas have a built-in ability to handle those perturbations that can be fairly easily predicted, application of very short-term emergency measures may be somewhat more troublesome. However, if the quotas were modified such that they had time parameters assigned to them, these problems may be eliminated.

3. Other types of regulation. With the exception of truly short-term emergencies, there may not be a very large need for other types of regulations if the individual quotas are granted on a percentage basis. The existence of nursery grounds where young fish are particularly susceptible to harvest and other such clearly defined biological issues are the exception, for which it is necessary to use closed seasons or closed areas where appropriate.

Fishermen's quotas will not in general require detailed regulation of the actual operation of the individual fishermen. However, in order to take into account problems related to age of catch, particular stock being exploited, interdependent species, place and time of capture, and vessel congestion, it may be necessary to modify fishermen's quotas to some degree. That is, a quota may be for a particular area at a particular time of the year with a particular type of gear.

It is recommended, of course, that such modifications not be instituted unless it is absolutely necessary and then they should be kept as simple as possible. It is necessary to grant the fishermen as much freedom as possible. The quota should specify exactly what

can be caught and then allow the individual as much freedom as possible. This will cut down on administrative expenses and encourage economic efficiency by the individual fisherman.

4. Intrafishery conflicts. Fishermen's quotas appear at the surface to be a very useful way to handle intrafishery conflicts. Individual quotas can be distributed to individuals in the various segments of the fishery. Obviously there may not be complete agreement on the most equitable sharing system, but there is the possibility of directly considering each segment. Likewise if there are gear or space conflicts, their quotas can be set up to take account of this. For instance a trawler while working on his quota would only be able to fish at certain times and in certain areas where he did not conflict with the operation of fixed gear operators. Economic efficiency should be considered, however, and constraints should not be such that costs rise inordinantly with respect to the distributional benefits received.

It is also true that if the quotas are transferable some of the intrafishery conflict can be eliminated by one group buying out another. The segment that decides to sell will not have left the fishery involuntarily but will have received some of the capitalized value of the fishery in return for leaving.

5. Multipurpose fleet problems. Fishermen's quotas can be very effective in solving multipurpose fleet problems. If all the related fisheries that are harvested by the multipurpose fleets have fishermen's quotas, or another form of limited entry other than licences, the individual boat owner can plan the utilization of his vessel in a strictly optimal way. He can buy or sell shares in the various fisheries or be prepared to pay the taxes when necessary, such that the annual profit for his vessel is maximized. If the limited entry schemes are set up such that the number of shares is optimal, private operation of the vessels will guarantee that the total catch will be harvested as cheaply as possible. Also all vessels will be free to transfer from fishery to fishery if they feel it is to their advantage.

Within a particular fishery this will guarantee that the harvest will be optimally spread out over the season so as to generate proper price and supply levels. With no quotas, the race to get fish will often mean that there will be peak landing periods as soon as the season opens. This will create problems for the processor and will cause the price to fluctuate over the course of the season. With quotas, however, there will be motivation for some individuals to postpone their harvest to take advantage of the potentially higher prices in off peak periods. As a result of this intraseasonal switching, the total allowable catch will be spread through the year so that there is a fairly stable price pattern.

6. Distribution. The distribution aspects of the fishermen's quota system will depend upon the original implementation schedule. If the rights are distributed based on historical catch and participation rates, the actual distribution achieved will most likely be acceptable to the industry. (Whether it will be acceptable from a national point of view is uncertain). There may be special issues such as new boats or captains who were ill over the last few years, etc., but special hearings and adjustments should be able to handle them. The main issue here is that unless specific steps are taken to the contrary the economic rent from the fishery is distributed to the fishermen themselves. More particularly it is distributed to the fishermen who receive the initial shares. To the extent that the fishermen's quotas are effective in reducing overcapitalization and increasing the total catch per unit of effort, the value of the quotas will go up. However, once they are sold, this increased value will become part of the selling price and so while an initial fisherman will be making a higher return on his investment than he was in open access, a new buyer will have to pay more to get into the fishery and his return on total investment (labour, boat, and fisherman's quota) will be about normal. The initial owner will capture the capitalized value of this increased productivity if he sells his quota share. For this reason some people have recommended a tax on the first sale of the licence so as to capture this amount for the public coffers. This is one way to redistribute some of the gains from management to the general public.

If the government is concerned with the distribution of rights that are ultimately achieved, it could purchase fishermen's quotas and give or sell them at a subsidized rate to other individuals whom it feels deserve a share of the catch. For instance they may want to provide shares to unemployed individuals in isolated areas, etc. In addition, if there is opposition to granting the full rents from the fishery to individual fishermen, a fisherman's quota scheme could be supplemented by various combinations of annual charges or royalties on landings such that some or all of the rent is appropriated by government.

7. General effects on prices and employment. As mentioned above, due to the private ownership of catch shares, there will be no rush to harvest the catch unless there is a fairly significant change in the catch per unit of effort over the season. This will allow for a more orderly annual harvest providing a steady crop throughout the year with relatively stable prices. This will allow processors to avoid peak load processing capability and as such will have lower processing cost.

It should also be noted that the existence of property rights to the fishery allow for the potential of monopoly or of vertical integration of the industry. If one firm can obtain many shares of a particular fishery, it may derive monopoly power for itself. This would, of course, eliminate the common property market failure but only at the extent of introducing a monopoly market failure. The extent to which this occurs will vary among fisheries. However, even if a person obtains a large share of a particular fishery he may not have monopoly power due to competition from other sources of similar fish. Also the fact that processors can buy up shares may lead to vertical integration and the economic inefficiencies that may follow. In some instances vertical integration may result in economic efficiencies, and therefore whether this is potentially good or bad will have to be decided by a case-by-case basis. A limit on the number of rights that any one entity could control may be sufficient to eliminate potential monopoly or vertical integration problems.

The very attribute which allows for monopoly or vertical integration, however, also allows for ease of entry of new entrants. If the quota shares are divisible into small units, entry will be easy relative to say a licence programme. With a quota system an individual can start out small and buy a few shares. If things improve he can gradually increase the number of his shares and the scale of his operations. With a licence programme it will be necessary to purchase a licence to enter and because they are non-divisible, the price will be more than likely quite high. This will discourage entry except to wealthy or established entities with good credit for large loans.

8. Capability of achieving biological goals. Because the fisherman's quota can be set up in terms of a percentage of an allowable catch each year, the potential to achieve biological goals is very high. This is because changes in biological conditions can be directly considered. Also the fact that the regulation is ultimately in terms of physical amount of catch means that to the extent it is enforced, the biological goal of achieving a desired catch (though not necessarily a desired level of fishing mortality) will be achieved.

9. Interdependent species. The existence of interdependent species will make it difficult to set up a meaningful fisherman's quota scheme. To the extent that the fisherman has some control over what he catches and to the degree that a fisherman's quota for a certain species can be modified with penalties for by-catch of other species such that it will encourage a change in techniques or areas fished such that by-catch is reduced or eliminated, a fisherman's quota system may be feasible. However when there is truly incidental catch, fishermen's quotas can be used only if they are expanded to include all of the interdependent species. This can pose some very difficult problems, however. For one thing it may be difficult or impossible to prevent undue stress on one particular species under such a general system. Also if one species is more highly valued than another, individual fishermen may be motivated to discard lower valued species at sea so as to not use up their quota on them. In instances where problems such as these are relatively unimportant, a broadly based fisherman's quota programme may work in an acceptable manner however.

10. Vessel and fleet operating efficiency. To the extent that the quotas are transferable, vessel and fleet operating efficiency should be assured. Initial distribution of the shares, if the total effort is to be reduced rapidly and especially if they are based on historical participation, will more than likely mean that each individual will be given a small share. Therefore there will be motivation to buy and sell these shares until those operating have enough to operate at the minimum point on their average cost curve. The degree to which this can occur will depend, in part, upon how divisible the fishermen's quotas are. The smaller the unit, the easier it will be for the fisherman to make micro adjustments in his level of output to take advantage of economies of scale.

One potential problem for vessel operating efficiency is the fact that the amount of allowable output associated with a percentage of fisherman's quota is, by definition, variable from year to year. This can present a problem in choosing the optimal size fishing vessel to use with a given number of shares. But the problem is not much greater than those faced by many other firms who must deal with uncertainty. A farmer may have difficulty determining the optimal size harvesting machine, due to the variances in crop size due to weather, or a vegetable processor may have similar problems determining the optimal sized plant for the same reason. The solution depends upon the expected amount of utilization each year. In the case of the fishery, the firm will want to minimize the sum of two potential losses. They are the loss that results from having too small a vessel when there is a good year, and the loss that results from having too large a vessel in a bad year. Although this problem will exist with fishermen's quotas, one should not judge that system too harshly. It certainly will exist in other programmes as well. In addition a management scheme should not be expected to solve all problems. A fisherman's quota programme will reduce the overcapacity that results from common property and as long as it can place the individual firms in situations comparable to those that exist in other industries, that should be enough.

There are other issues concerning vessel and fleet operating efficiency dealing with age and timing of catch, etc, but they have been discussed under item 3. Other Types of Regulation, above.

11. Technological advance. As long as it is not necessary to modify the fisherman's quota system with other regulations to control for a complex fishery, or for short-term emergency situations, technological advance should be optimum in the fishery (see item 2, Flexibility, and item 3, Other types of regulation above). As new techniques become known, fishermen can buy or sell quotas so that they can take advantage of these new techniques. If it is possible to increase the scale of operation and thus fish more efficiently, a fisherman can purchase more quotas in such a way that he can take advantage of new developed economies of scale.

12. Research and regulation costs. Research costs will probably be no different than with other comparable schemes, except in highly variable stocks of short-lived species. For these the continuing research required to determine the total quota for each year (e.g., from surveys of juvenile fish) may be very expensive. Regulation costs may be quite high for fishermen's quotas, at least during the implementation period. For one thing it will be necessary to consider the exact catch of every vessel that is fishing. And when the vessels can vary their allowable catch by purchasing or selling shares of the fishery, the monitoring problem can become more difficult. To overcome this, I would recommend the following. The share of the fishery should be issued on a percentage basis and then annually the owner should receive a set of coupons equal to the weight that he is allowed to catch according to his percentage share and the total allowable catch. It will be illegal to land fish from this fishery without one of these coupons. These coupons, as well as the basic quota itself, should be freely transferable. By making the coupons transferable, it will be possible to allow for short-term adjustment. For example, a fisherman who towards the end of his session, has a very large catch such that the total catch is greater than his quota, can just buy the appropriate number of coupons before selling his catch. It is not inconceivable that an active market for coupons will be

developed with many transactions taking place via radio-telephone as ships head into port from the fishing grounds. To the extent that the fishery requires extensive processing this should be fairly easy to enforce. It will not be necessary to watch landings at all. Rather it will only be necessary to require that the processors collect the coupon when he purchases the fish. Then before he seels his final product he must have sufficient coupons to back up the amount of raw material contained in it. It will not be necessary to check which boat lands the fish. It is only important that no fish are harvested beyond the amount allowed by the number of coupons. Significant penalties on the processor should guarantee that no fish are purchased without the appropriate coupons. This in turn will discourage fishing when coupons are not available at reasonable prices.

As with taxes, it will be difficult to enforce a fisherman's quota programme if catches are primarily sold fresh or if there are a very large number of small processors. In fact it is hard to estimate which of the two would be more difficult to enforce without some knowledge of the institutions of the particular fishery. However, to the degree that the point of final sale can be monitored, the coupon system should make the quota scheme superior on the grounds that it will not be necessary to monitor individual landings.

13. Freedom of individual participants. Fishermen's quotas which are transferable rank very high with respect to freedom of individual participants. Fishermen, to the extent that they are not limited by time and area constraints, can fish anytime anywhere they choose. They can also sell and buy shares so that they can retire from the fishery or expand their operation as they choose. It is quite easy for individuals to enter the fishery for the first time. Granted it will not be as easy as in an open access situation, but it will certainly be as easy as it is in any other business. In a farm it is necessary to buy a tractor, seeds and a piece of land to work, whereas in an open access fishery all that is necessary is to buy a boat, nets, etc. Under limited entry the fisherman will have to buy the equivalent of a piece of land to utilize with his boat, nets, etc.

C. Licensing Programmes

1. Implementation. The first step in any implementation programme is to get the legislative approval. In the United States, Canada and Australia at least, legislative approval for licensing programmes has been obtained. Because of its similarity to the status quo, at least in the initial stages as instituted in the above countries, licence programmes appear to have the best chance of being approved of the limited entry programmes discussed here.

The basic idea of a licensing scheme is to restrict the number of participants to a fishery such that they exert the desired amount of fishing. Several issues are important here. First exactly what should be licensed? The fisherman, the boat, or the unit of gear? Also what is the rate at which the optimal amount of licences is to be approached?

For reasons of economic efficiency, it is usually best to licence the vessel. A more complete argument for this is presented below. It is useful to point out, however, that while licensing the boat is usually superior there may be special cases where another item is more appropriate.

Once the item to be licensed has been determined, it is necessary to decide how the licences are to be distributed. Will there be an immediate reduction in operating units or will there be a time span over which the number of units is reduced? Political reality usually necessitates the latter course. It is very difficult to make abrupt changes in the make-up of the fishing industry. In addition a slow adjustment in the amount of fishing may make sense in economic efficiency terms especially if the vessels to be eliminated from the fishery have no alternative use. If they are at least covering their variable costs and if they are not causing significant biological damage, it may often be best to allow them to fish until they are fully depreciated. And although I hesitate to make comparisons between human beings and pieces of capital equipment, under the same conditions it is probably better to allow all established fishermen, with no skills, and no potential

for retraining for other types of work, to continue to fish until their retirement rather than make an instantaneous adjustment to the optimal level of effort. Of course the same argument can be made on income distributional or human compassion grounds as well.

The usual starting point for a licence programme is to place a moratorium on entry into the fishery. It is sometimes difficult to specify exactly who has been in the fishery, but these problems can be handled. It is usually necessary to specify an amount of participation over the previous few years (days fished per season, total catch per season), or an indication of intent to participate such as the construction of the vessel.

It is important to allow for an efficient part-timer and multipurpose fleets to be adequately considered. At the same time, however, every effort should be made to cut out all "deadwood" from the fishery at the outset if possible. Otherwise a licence granted to a "canoe" in year one may come back to haunt administrators as a very large vessel several years later as the entry programme begins to be effective. It is difficult enough to make the adjustment to a reduced amount of effort without allowing for illegal claims of participation. Individuals will try their best to get included in the moratorium, because they will want to gain some of the returns of the limited entry programme if it is successful.

It is important to realize that in any fully developed open-access fishery a moratorium can only be a first step in an optimal management scheme using licences. If the fishery is overcapitalized, a moratorium will only prevent further capitalization, it will not reduce it. Therefore there must be some way to reduce number of participants. There are several ways to do this. One is to allow licensed fishermen to retire until an optimal number remain. This may appear to be an equitable way of reducing effort, but it does have some troublesome short-term effects. All fishermen know that they have to remain in the fishery to obtain the benefits of the limited entry programme. Therefore they will be motivated to continue fishing long beyond their normal retirement age. As a result the fleet may soon consist of very old individuals or very old vessels, which will be an inefficient way to produce effort. Another weakness of this system is that it is a distribution of the wealth in the fishery on the basis of longevity.

Perhaps the most equitable way to achieve a reduction is to set up a buy-back plan where fishermen can sell their licences back to the regulatory authority at a price that is agreeable to both. This way those that leave the fishery can do so at the time they desire and in the process can capture some of the gains from the regulated fishery.

2. Flexibility. The amount of inherent flexibility in a licence scheme is quite low. All that has been done is to limit the amount of one or more crucial inputs. There are no built-in means to adjust to emergency situations or to stochastic fluctuations. Subject to the input constraints, an unadorned licence system would permit the fishermen to operate in any area or manner they desired. As will be discussed below, however, these input constraints are quite important as far as economic efficiency is concerned, but they often have little effect on the long run amount of effort produced. And by their very nature, existing constraints are of little or no use in reacting to emergency situations to reduce effort in the short run. Therefore it will be necessary to be able to institute other types of regulations such as closed areas, closed periods, or absolute closures for short periods of time when such emergencies arise.

A licence programme is probably more flexible than a tax programme for the simple reason that there will be some upper limit on the number of fishermen or vessels that will have to be controlled in emergency situations. It is, however, less flexible than either a fisherman's quota or an effort share programme because it lacks their internal ability (as a result of the percentage shares) to adjust to yearly fluctuations.

3. Other types of regulation. Although licences lack inherent flexibility to adjust to emergency and stochastic biological problems, they are usually quite compatible with other types of regulation which handle these problems. Absolute closures or closures in certain areas or time periods can be introduced easily in a licence programme.

Although licence plans are compatible with other regulation schemes, they have the unfortunate attribute that they also will necessitate many other regulatory elements. This is so for at least two reasons. First, if the licence scheme is set up such there will be a moratorium followed by a gradual reduction in the number of vessels, certain types of controls may be necessary to keep those that remain in the fishery from destroying or seriously damaging the stock during the period in which the fleet size is to be reduced.

Second, to the degree that a licensing programme is successful and catch per unit of effort increases, there will be natural incentives for those that remain to expand their fishing effort to take advantage of these increased productivities. Since a licence usually applies to only one facet of the fishing procedure (here we have recommended licensing vessels) fishermen have other parameters under their control with which they can increase effort. For example, using the same size boat the fishermen can use more gear, a larger crew, better finding equipment, etc. This will increase the actual fishing effort of the boat although at an increase in average cost. As a result the effort potential of the entire fleet will go up even though the number of licences stays the same. In order to achieve an actual reduction in fishing effort and hence catch from the fleet, it will be necessary to add other restrictions on the licence. That is, it will not only be necessary to restrict the number of boats but the type of gear or size of engine they use, when they can fish, etc., will have to be controlled. Fishermen are very ingenious at getting around these types of regulations and this ability will necessitate further rounds of extra regulations. Not only is the continuous cycle of: regulation - activity by fishermen to diminish the effect of regulation - further regulation - etc., very expensive in itself, but the very nature of extending effort under those constrained conditions will cause the cost of producing effort to go up. Therefore the potential economic benefits from fisheries regulation will be reduced or lost (see Pearse, 1978, and Pearse and Whilen, 1979, and the discussion in item 10 below).

4. Intrafishery conflict. There is nothing in a licence scheme per se that directly addresses the issues of intrafishery conflicts. Making sure that each segment of a fishery has an equal chance at an initial licence may be one way to eliminate some of the distribution problems but competition between gears, etc., will not necessarily be addressed. To the extent that licences are transferable there may be potentialities for one segment of the fishery to purchase licences from other segments, which will allow for a reduction in potential conflict and at the same time provide an opportunity for individuals to leave the fishery with some of the benefits of management. During the adjustment phase from the moratorium to the optimal amount of effort, the intrafishery conflicts will probably become more extreme. Any particular reduction programme will likely affect different segments of the fishery differently and this will cause considerable political and economic unrest.

5. Multipurpose fleet problems. In general licence programmes rate fairly low in their ability to solve multipurpose fleet problems. In the licence programmes now in effect, a boat must continue to fish in a particular fishery in order to keep his licence valid. This may well prevent him from moving into other fisheries for parts of the season when at the margin it would be more profitable to do so. This need not be the case, of course, if licence programmes are adequately set up to handle the problem when it is known to exist. For example, a fisherman with a certain licence may retain the right to fish in that fishery if he can show that he fished in a related fishery during an appropriate period of time. Other ways to solve the problem include combined licences that would allow multipurpose fleets to work in several related fisheries, or programmes which allow vessels to hold licences in more than one related fishery.

6. Distribution. Although the distribution aspects of a licensing programme are complex and related to the specific nature of its implementation, some generalizations can be made. First, unless there is a tax involved, the gains from fisheries management will go to the fleet owners rather than to the public, and, as in the case of fishermen's quotas, the individuals who are able to remain through the moratorium period will be the ones who will receive the gains. These gains will be in increased productivity while they fish or increased capital value of their licences when they sell.

It is also important to note that if there is a high degree of input substitutability such that fishermen can increase effort despite the constraints placed on certain inputs, all possible gains to the fisheries management can be dissipated through these increases in effort. That is, although there is not complete open access, there will still be completed dissipation of rent through the increase in effort by those allowed to fish. Of course, if the possibility of input substitution is low, this dissipation will not necessarily occur.

Another possible disadvantage of licences, especially if they are attached to vessels, relative to fishermen's quotas or effort share programmes, is that they will be less divisible. With the latter it will be possible to buy or sell small portions of allowable catch or effort. An analogous situation would not be possible under a licence scheme. It is only possible to buy or sell the licence itself. To the extent that each of these systems are equally successful in increasing the rents to the fishery, it follows that the price of a licence will be higher than the price of the smallest practical unit of a fisherman's quota or an effort share. If this is the case, it will be much more difficult for the small operator to move into the fishery. The fishery will likely be composed of large entities, perhaps even corporations, to the relative exclusion of small entrepreneurs.

7. General effects on prices and employment. As with other management schemes that attempt to achieve economic efficiency, it is important to realize the actual amount of fish harvested and hence the price of fish may go up or down. The important point as far as the general economy is concerned is that if overcapitalization is reduced, the gross value of goods and services produced in the economy can be increased if redundant resources removed from the fishery can be allocated to other uses. As discussed above and will be amplified below, licence programmes do have a tendency to prevent such redundant resources from leaving the fishery, and in fact may encourage more to enter. So to this extent the true gains from fisheries management may not be achieved.

In addition, although the number of boats or individuals are limited there may be no reduction in the desire to harvest the fish as early in the season as possible due to the fact that there is no real private ownership of the stocks. Therefore there may still be peak load problems in harvesting and processing as well as fluctuations in landing and prices.

One beneficial aspect of the licences as far as general economic effects are concerned is that it may provide more power to the fishermen to negotiate with processors. In the past processors, because of their relatively small numbers and the nature of open access entry, have usually had considerable power in setting prices. The existence of licences which restrict the number of individuals the processors can deal with will tend to shift the balance of power. The same argument holds true for other types of limited entry programmes as well.

8. Capability of achieving biological goals. There are many weaknesses to a licence programme as far as achieving biological goals. This should be obvious from the discussion above. First, if a moratorium is used, it will only prevent other boats from entering but it will not force a reduction. Therefore it will be necessary to supplement the licensing programmes with quotas or other restrictions to achieve a reduction in effort, at least during the transition period. However, even in an ideal situation, due to desire of the fishermen to increase their productivity as catch per unit of effort goes up, it may be difficult to establish the ideal number of licences to obtain a specified amount of fishing. Everytime the licences are restricted and catch per unit of effort

goes up, fishermen will be encouraged to increase the amount of effort they can produce given their licence, and hence the biological effectiveness of the controls will be diminished.

9. Interdependent species. Licensing, by itself, cannot address the by-catch problem. In order to do so it will have to be modified to include other regulations, such as gear restrictions in particular areas, etc. Licences, however, do have the advantage that they do not encourage discards of potentially valuable catch that would otherwise have been kept. Such a phenomenon is entirely possible with fishermen's quotas.

10. Vessel and fleet operation efficiency. It should be obvious at this point that licence programmes will have severe problems with both vessel and fleet efficiency. The problem with fleet efficiency is directly related to vessel behaviour. When each vessel is operating inefficiently it is very difficult to specify an optimal fleet size. To review the cause of the vessel inefficiency is the fact that a licensing scheme will only restrict one or two inputs while allowing the fishermen freedom to increase fishing effort with other inputs. This will cause effort to expand at a cost higher than would otherwise be the case. There will not only be too much effort but it will be produced at a higher cost than is necessary. In some sense this is worse than open access where there is too much effort but at least it is being produced efficiently.

The selection of the item to license can have an effect on the amount of inefficiency that can result from a licensing programme. It is generally the case that a licence on vessels will be better than a licence on fishermen or certain types of gear. If the fisherman is licensed, he will have complete freedom to increase his effort by changing boat size, gear type, etc. However, as Crutchfield (1979) has argued, if the vessel is licensed, there is likely to be a point where further increases in effort are impossible even if there are no restrictions on other inputs. A vessel is (para-phrasing Crutchfield) just a platform upon which the other inputs of fishing are placed. After some point, there is just no more you can do with that platform. The arguments for limits to possible expansion is even stronger if the licence restricts tonnage and other characteristics of the vessels. This is not to say that there will be no inefficiencies if the licence is placed on vessels. Quite the contrary is true if the limited entry programme works, because there will be incentives to get around the constraints. However, depending upon the amount of input substitutability, there may be a limit to which this inefficiency can be carried. To the extent that it can be limited, there is a possibility of reaping some of the economic benefits that are possible from rationalization of fisheries. Pearse and Whilen (1978) have studied the British Columbia licence programme and, although their results are mixed, it appears that, to this date, not all of the gains to management have been dissipated by inefficiency.

11. Technological advance. A licence programme will, more than likely, cause inappropriate amounts and types of technological advance. Proper technological advance reduces the cost of producing effort and a proper timing of technological advance will not replace fishing gear as long as it is covering variable costs. With a licence on one particular input, technological advance will be perverse in the sense that it will attempt to increase effort subject to the constraint of a fixed input. For example, if boat size is limited, technological advances toward increasing effort while keeping the vessel size the same will be encouraged. However, the optimal line of advance may well be to increase the boat size along with other inputs.

It is also likely that technological advances will be implemented in an improper time pattern. This is because there is still a race to catch the fish even though the number of contestants has been restricted. As long as the catch per unit of effort is going up and an individual feels that by introducing a new technology he can gain, he will do so even if it forces other units with different types of technology to become unprofitable.

12. Research and regulation costs. Research costs will probably be the same in this programme as in others. However it may be necessary to do research on how fishermen will react to constraints on one input and what they will try to do to get around these constraints. Similarly it will be difficult to determine the amount of actual fishing power that is being exerted when the nature of the vessels changes constantly. This is especially true if there are many types of gear covered under one licence programme. Regulation costs are likely to be quite high due to the fact that extra regulations will be necessary to counteract the fishermen's desire to increase effort producing ability.

13. Freedom of individual participants. Of the types of limited entry studied in this paper, the licence programme will probably have the smallest amount of individual freedom. This is because if it is to be effective, other regulations will be necessary to restrict the fisherman's ability to produce effort. If these constraints are not used, the individual's freedom will be high but the biological and economic effectiveness of the programme will be reduced if not destroyed.

D. Effort Share Programmes

Effort share programmes are very much analogous to fishermen's quotas. The only difference is that the property right to the fishery is stated in terms of fishing effort per year rather than terms of annual harvest. Similarities between the two are so great that a detailed analysis of effort share programmes is not necessary. Accordingly the discussion of each of the problem areas will be brief and will only contain the analysis of how they differ from fisherman's quota systems. In some cases, no comments will be necessary.

1. Implementation. All of the problems associated with implementation of fisherman's quota schemes will be present in the implementation in an effort share programme. In addition, however, there will be the problem of defining and measuring effort. This will be no small issue, especially in cases where there are many types of boats and the fish are harvested in different seasons and different areas. Accordingly it will also be difficult to use an historical participation rule to distribute the effort shares.

2. Flexibility. See discussion under fisherman's quota system.

3. Other types of regulation. Although it may be difficult to define precisely what effort is, the very nature of an effort share may make it easier to add other types of regulation if necessary. That is, if age at harvest, place or time of harvest, or the congestion between types of effort are important in a fishery, it may be easier to address these issues in a system where the general focus is already on the make-up of effort.

4. Intrafishery conflicts. See discussion under fisherman's quota system.

5. Multipurpose fleet problems. See discussion under fisherman's quota system.

6. Distribution. See discussion under fisherman's quota system.

7. General effects on prices and employment. See discussion under fisherman's quota system.

8. Capability of achieving biological goals. Because the relationship between effort and actual harvest is difficult to pin down, the ability to control actual mortality by controlling effort is less than perfect. Therefore, the ability to obtain a specific fishing mortality in a given year is weaker under a system of effort shares than it would be under fishermen's quotas. However, effort shares have one very big advantage in that they may be more stabilizing in the long run. With a quota system the maximum permitted harvest will be caught in almost all conceivable circumstances. However, if there has been a misreading of the biological system and the stock size is actually smaller than estimated, the permitted catch will be larger than optimal. This will tend to push the stock size even

lower. On the other hand, if the biological estimate erred in the other direction, and stock size is underestimated, the estimate of the allowable catch based on that underestimate will allow a smaller than optimal harvest which will cause the stock to increase. Fisherman's quota will therefore tend to increase the range of the fluctuation in stock size.

Effort share programmes will do the opposite. If the stock size is overestimated, and so a relatively large amount of effort is allowed for, catch will be greater than optimal but certainly not as great as it would have been under a quota system. The specified amount of effort simply cannot catch as much fish as it would if the stock were larger. In the reverse situation, if the stock size is underestimated, and the allowable effort level set lower than it actually should be, the amount of fish actually harvested will be greater than expected due to the high productivity of effort given the higher stock. In this way, when stocks are underestimated there will be a tendency to take a larger than predicted catch and when stocks are overestimated there will be a tendency to take a smaller than predicted catch. This will reduce the fluctuation of the stock size.

9. Interdependent species. See discussion under fishermen's quotas.

10. Vessel and fleet operating efficiency. If fishing effort can be defined in a fairly straightforward manner, effort share programmes should be comparable to fishermen's quotas as far as economic efficiency is concerned. For example, if effort can be defined as days fished with a particular type of gear, each fisherman will be motivated to organize his activities such that the actual cost of producing that effort is as low as possible in much the same way that the owner of a fisherman's quota will be motivated to operate as to minimize the cost of obtaining a given level of catch. As long as there are not too many constraints implied in the definition of effort, the fisherman should have a free hand in selecting the size of boat, the operational levels, etc. If he is a profit maximizer, he will do so in a cost effective manner. He will also be motivated to buy extra shares if that will allow him to take advantage of economies of scale. On the other hand, if in order to effectively define effort, it is necessary to include such things as time and place of operation, size of boat, number of crew, etc., the chances for obtaining economic efficiency will diminish with the lost freedom of the individual fisherman. In these instances the effort share programme will have many of the same problems as a licence programme. The authorities will have to specify exactly what type of operations are permitted with each effort share, and the fishermen will be motivated to increase their actual effort given these constraints. In general, then, the more complicated the fishery, the lower will be the chance of obtaining economic efficiency with an effort share programme.

11. Technological advance. Effort share programmes may have counteracting tendencies with respect to technological advance. Again in the simplest cases, fishermen will be motivated to produce their given amount of effort as cheaply as possible and this will encourage proper technological advance. In some instances, however, technological advance will, by its very nature, change the definition of effort. Therefore the effort shares of those individuals who institute the technological change will have to be changed. For example, given a certain level of technology, a specified amount of fishing mortality can be generated with ten days of effort. Technological advance may make it possible to obtain the same fishing mortality with two days of effort. In this case, it will be necessary to reduce the effort share of each individual by 80% in order to properly utilize the fishery. As a result there will be no net gain to the individual fisherman who makes the effort to improve himself. If fishermen expect that the only result of their technological advance will be a corresponding reduction in the size of their effort share they will not be motivated to allocate time and energy to research and development.

12. Research and regulation costs. Again because of the difficult problem of defining effort, especially in the presence of technological change, the research costs of effort share programmes will be quite high. Also the extent that it is necessary to define effort in terms of area fished, particular types of gear, etc., regulation costs will be higher than in a simple fisherman's quota system because at sea enforcement may be necessary.

13. Freedom of individual participants. Again depending upon the simplicity with which effort can be defined, the freedom of the individuals can be similar to a fisherman's quota. In the simple cases, the fisherman will have complete freedom to produce his effort share in any way he sees fit. However, where effort is a very complicated concept, the regulations will have to specify more and more of what the fisherman can do to produce his effort share and so the freedom of the individual will decrease.

SECTION 5

Summary and Conclusions

The one basic conclusion that follows from the above discussion is that there are advantages and disadvantages of each type of limited entry in addressing each of the defined problem areas. It is impossible to state a priori which one will be most suitable in a given situation. In order to determine which should be used in a given situation, it is necessary to consider the specific biological and economic characteristics of the fishery, and the specific goals and objectives of management. The framework used for general comparisons above will be useful for making the specific comparisons for a particular fishery. A useful procedure would be to make use of the principles outlined above to establish the most appropriate version of each of the limited entry programmes for the particular fishery. Then each should be ranked according to how they affect, or are affected by, the different problem areas. Using this information in combination with the different priorities or weights that are attached to the different problem areas, it should be possible to select an appropriate limited entry management scheme. This last point is very important. Different countries will place a different emphasis on each of the thirteen problem areas above, and therefore how a particular scheme rates in some of the areas may not be significant if those areas are not given much importance.

With respect to the above procedure, a further point is in order. The process of determining the most appropriate version of each of the limited entry types should be done with care. Although each type has certain weaknesses, as explained above, certain modifications can be made to lessen their impact. If there is going to be a useful comparison, it is imperative that the schemes actually being compared are the best versions of each of the types. In most instances the best version may be combination of the basic format of the particular type and some of the more traditional regulation measures as well as certain aspects of the other limited entry types.

A further aspect of the general question addressed in this paper not discussed thus far , but still very important, is the stage in the development of a fishery at which it is appropriate to institute controls. In almost all of the discussion above, it was implicitly assumed that the fishery in question was overdeveloped and had an excess amount of capital and labour. This may have given the impression that fisheries that are in the process of development do not require management attention. This is not the case. By instituting management at an early stage, it is possible to ensure that the fleet never becomes too large. As Gulland (1978) points out, implementing management programmes earlier in the development process before the problems of overfishing become severe, besides allowing for benefits to be achieved earlier, also prevents adverse effects that often accompany regulation instituted later. The most prominent of these effects is the fact that contracting effort can be a very expensive and painful experience. Vessels may have to be retired early and individuals may be forced to find alternative employment. It is easier to avoid this over-expansion than to bear the costs of contraction. Another related point is that if the over-expanded industry has political power it may utilize it to prevent or impede the needed contraction from taking place at all.

One conclusion, which does not follow from the argument in this paper, but was in fact one of the premises upon which it was based, is that if limited entry, in one form or another, is not used, it will be impossible to achieve any long lasting economic benefits from regulation.

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APPENDIX 2

AN INTERNATIONAL INSTITUTE OF FISHERY MANAGEMENT

by

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1. BACKGROUND

Managing fisheries is a far more complex task than most imagine. In years past, the smoothly efficient, long-distance fishing fleets of the world roamed the seas and took fish more or less at will. Markets worked to equilibrate fish supplies with world demand, and few gave more than a passing thought to the matter. The concept that fisheries might need management was nearly as alien as the prospect of a dwindling energy supply; but, as with energy, world events have forced a major reassessment and created urgent demands to use this precious marine resource intelligently.

Fish are "renewable", to a point. Making the best use of the resource and ensuring that it can survive in sufficient numbers to replenish itself are not trivial tasks. Indeed, attaining the delicate balance between "making best use" and simply "over-using" the resource requires equal measures of good science, good politics, good management, and good luck. Of the four considerations, science and management can be attended to, but these require extraordinary commitment and the concentration of extremely scarce technical and scientific resources. This truth has been stretched to a near breaking point by recent changes in the world order.

Much of the world's supply of fish has been "nationalized", in effect, by provisions of the Law of the Sea Conference. As a result, some 156 national entities (119 of which are developing nations) are now rapidly laying claim to all fish resources within 200 miles of their shorelines. And, "each country apparently has every hope of reaping all economic benefits possible from the legal move, many of the poorer nations lack the experience and know-how to take stock of their fishery assets and develop sound plans for managing them."1/

This problem has been sharply recognized in the following comments by H. Kasahara, an FAO fisheries expert. 2/

> On a worldwide basis (a serious problem) is the lack of expertise in many of the developing countries, some of which have rich resources in waters under their jurisdiction. These countries are swamped with advice, technical assistance, equipment selling, fishing agreement or joint venture offers, international funding proposals, etc. from various sources. A combination of these usually tends to result in over-capitalization by building up a fishing fleet and shore facilities too rapidly since they appear to be cheap or sometimes free. Few of these countries do realize how difficult it is to develop profitable fisheries where technical expertise, managerial skill and trained personnel are lacking. The administrators of at least some of these countries are incapable of sorting out good advice and offers from bad ones.

Managing a fishery well is not simply a matter of having and using good scientific advice, however. A full appreciation of the fishery system quickly shows one that biological considerations, as important as these undoubtedly are, comprise but one of a veritable constellation of factors that must be understood and taken into account if the fish resource is to

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1/ Lucia Mouat, "Helping Coastal Nations Manage their Ocean Fisheries", Christian Science Monitor, 23 August 1979, p.3

2/ H. Kasahara, "Some Thoughts on Management", unpublished comments to the Working Party of the Advisory Committee on Marine Resources Research, Rome, Italy, 6 December 1978

be used well. For instance, a decision made by an economist in some faraway development bank to add to the capital infrastructure of a nation may be made for understandable and physically rational reasons; however, such a decision may impact on the fishing resource with devastating results. The problem, too simply stated, is that the environment is connected through many non-obvious links, there are many more individuals involved with the fishery resource than most realize, and the variety of interests, objectives, and purposes these individuals represent nearly necessarily leads to confusion, conflict, and other intolerable outcomes.

Lack of appreciation of the full complexity of the man-fish system and environment has become increasingly unacceptable as pressure mounts against the world's fish stocks and as nations exert their claims to ownership and exclusive control through extended jurisdictions and other devices. For instance, what does a nation do when an over-capitalized fishery collapses? No one really knows very much about this tragic eventuality, although it has occurred and its prospect looms large. What kinds of information might have given some advance warning of *in extremis* collapse in a fish stock? Who should be generating and monitoring this situation; who should be told; and what could and should be done to limit the effects of such a collapse and on the lives of fishermen? For many of the newly vested fishing nations making best use of their property right may entail massive marketing and educational campaigns so as to acquaint a home populance with the importance of fish and fish products (as a consumption good or as an item for export), especially in instances where such have not been an integral part of the cultural heritage and experience. Who is to mount such compaigns? What kinds of programmes work and are appropriate for which situations? No one can answer any of these questions, but these are precisely the kinds of management questions that one can foresee confronting the fishing nations of the world. Many other, even more fundamental, questions can be posed that confront fishing managers around the world.

Who is a "decision-maker", that is, who exerts influence or power over actions that impact on fisheries? Is it the research scientists who knows more than anyone else about a specific stock of fish in a given location somewhere in the world? Is it an international lawyer immersed in the fine points of negotiation of a bi- or multilateral agreement or treaty? Is it an official in one of the development agencies; in one of the regional fishery associations; in one of the local, national, or regional fishery or natural resource administrations? Or is it some as yet unidentified individual whose actions have implications for the fishery resource, such as a tanker captain who runs his heavy-laden vessel aground or an oil rigger whose luck runs out in a monumental blow-out. There is no general answer other than to say that some, all, or none may be involved in a given setting at a specific time. However, it is safe to say that whoever takes responsibility for a fishery resource should be acutely aware of the complex web of obvious and not-so-obvious individuals and institutions that participate in the man-fish system. (Table 1 is the form of inquiry we have in mind here).[3/]

There is a large present and probably increasing need to expose and prepare managers for a world having these and other extraordinarily complex features. While the precise approach to be taken to accomplish this end, and others associated with the preparation of managers for the 21st century, must be an unending and continually improving one, the basic requirements are discernible. It is a pressing matter according to Kenneth Lucas, FAO Assistant Director-General for Fisheries: "Our top priority is to help those who want to help themselves ...(it is) urgently necessary".[4/]

The following discussion lays out options for ways to train the world's fishery managers. It is not the only means by which this could be done, nor is it necessarily the best proposal for doing so; however, many of the central elements in the teaching and training tasks to be confronted are evident and will be prominent in any specific proposal that is enacted. The paramount consideration is to move ahead, and to do so constructively and with dispatch.

3/ Trying to identify and then connect the more obvious participants proved to be a challenging task for those assembled in the ACMRR Working Party in December 1978. FAO Fisheries Circular Nº 718, FIR/C718, pp. 5-6

4/ Cited in Mouat, *op. cit.*

Above all those interested and deeply concerned about the world's fisheries - especially their intelligent and productive management - must set aside petty jealousies and institutional self-interests and pull together vigorously toward the overriding goal of preparing the fishing nations of the world to meet their responsibilities, to themselves and to all of mankind.

Table 1

Key participants and their problems in the fishery system

Participants	Problems
Analysts:	Data collection, theory development, methods applications. Topics selected for study rationalized according to disciplinary and professional imperatives and incentives, not comprehensive societal ones
Biological scientists	
Social scientists	
economists	
political scientists	
sociologists	
anthropologists	
international relations	
Earth scientists	
Professions:	Application of specialized tools, languages, and norms with respect to fish and fishery matters
Lawyers	
Operations researchers	
Planners	
Administrators	
public	
business	
Nutritionists	
Managers:	Budgets; institutional growth and survival; individual advancement; generation and control of specialized information. These general concerns persist through all levels of management, mediated by details of individual context
Local	
National	
Regional	
International	
Politicians:	Election; protection of constituents' interests; exercise of power (and its accumulation). ("Election" generally refers to the attainment and maintenance of position)
Local	
National	
International	
Fishermen:	
Individuals: commercial (owners, crew)	Earn living; survival
Individuals: recreational	Maximize pleasure
Associations	Maximize special interests
Processors/distributors	Maximize profits
Producers of boats and gear	Keep steady or increase demand for products
Suppliers of stores/fuel	Maximize profits
Environmentalists:	Minimize degradation; return to *status quo ante*
Consumers/Competitors:	
Food users	Steady supply: quality product, lowest price
Non-food users	Reliable, cheap factor of production
Food competitors (beef)	Keep/expand current market share; profit
Non-food competitors (oil)	Expand market share at profit
Mankind, generally considered:	Issues would have to be determined for each subgroup in specific locations at specific times. However, generally will relate to inequality, inequity, interdependence, etc.
Economic subgroups	
Racial subgroups	
Geographic/political subgroups	

Source: FAO Fisheries Circular Nº 718, FIR/C718, p. 91 (modified)

2. A GENERAL CONCEPTION OF THE MODERN FISHERIES MANAGER

To determine what a fishery manager should know and be trained to do, one needs to have some vision of what that individual could and should be doing if the goal of "intelligent and productive management" is to be attained. Such a general vision may, in turn, offer specific guidance about the kinds of training such individuals need.

First is the matter of being able to select specific substantive objectives: What does one want to accomplish, and how might the scientific, bureaucratic, and political resources at one's disposal be brought to bear to do so? One could think of this capacity as the ability to understand clearly the full complexity of any given situation so as to be able to design policies, programmes, and projects that will work and work well.[5/]

Second is learning how to become a spokesman. For instance, this would include learning more about the media, the procedures involved in holding hearings, making public appearances, and other acts intended to market policy and programme ideas related to fisheries. This is a particularly critical function, if one's sense of the level of misinformation and plain ignorance about fisheries is accurate. Furthermore, trying to get needed cooperation - an indeed eliciting ideas from others having a stake or interest in a fishery - will test the public relations and marketing skills of any manager. A good manager must be part teacher, part spokesman, and part public relations specialist; most of these basic skills can be taught.

Third is the well known problem of learning how to administer one's own money and manpower resources well, and this would include budgeting, organization structure and design, and personnel management - to name only several of the topics subsumed under the traditional rubric of "public administration". Few fisheries administrations are lavishly supported, and most managers will have to learn to stretch the few resources at their disposal by being efficient administrators.

Fourth concerns the problem of "synthesizing" or learning how to design an overall and relevant strategy that would allow a fishery policy or programme to gain initial acceptance and take hold over the longer term. Especially in areas where there may be no single "best" answer, an ability to perceive and calculate various ways to achieve one's goals will be critical.

Fifth is the ability to take action, that is, knowing how to put the strategy into effect, including attention to all relevant and important details. What are the tools at one's disposal, and how do you use them?

A fishery manager could be called on to carry out any of these general functions, and all should be represented in the curriculum of the IIFM in some form or another. It is insufficient, for instance, merely to be a consumate administrator, with all books and accounts in apple-pie order and all forms properly filled out. Likewise, it is at best a self-defeating manager who is a vigorous spokesman, but one who does so in ignorance of the realistic features of his environment. One has to have the facts in order and under control before taking public positions, no matter how sincerely felt those positions.

What specific managerial jobs or roles can be foreseen? Having some idea about real tasks that the would-be manager will be performing may also provide guidance to those responsible for the IIFM's programmes of study.

5/ A policy refers to broad strategic statements of objective, e.g., we wish to have full employment of those involved in the fishing industry. A programme is one of several specific means by which that policy is to be realized, e.g., investing in boats and shore facilities, training fishermen, and marketing the catch. A project relates to specific, fine-grained tasks undertaken to realize individual programmes, e.g., constructing a cannery in a given locale

3. POSSIBLE MANAGERIAL TASKS

One might think about structuring the working environment in terms of the tools at the fisheries manager's disposal. Doing so could give hints about the skills needed to function along a broad front. Table 2 identifies the more obvious of these tools and relates them to possible subject matters.

Table 2

Tools and Skills

Tools	Skills/Subject Matters
Access limitation	Law, biology, economics, engineering, surveillance techniques and technologies
Allocations	Regulation theory and practice, biology, politics, surveillance techniques (monitoring)
Investment	Financial theory, negotiations, bargaining, international trade
Conservation	Ecology, environmental law and practice, biology, public education, monitoring techniques and practices
Stock rehabilitation	Biology, public education, insurance and/or welfare mechanisms, monitoring techniques
Enforcement	Law (domestic and international), politics, engineering, biology

The thought exercise contained in Table 2 is not exhaustive, to be sure; however, it does begin to suggest the diversity of skills and subjects a manager should be aware of. Depending on the kind of job and the institutional setting in which the particular manager finds himself, certain of these tools and skills may be highlighted and others neglected or slighted. This is a specialized age, and one would be surprised if the general-purpose manager would be the more common. Table 3 begins the task of speculating on the kinds of jobs Institute graduates might find suitable for their talents. The intention here has been to keep wide open the definition of fishery management and, hence, to appreciate the diversity of employment opportunities and potential audiences an IIFM could and ought to have. If the scope of the training function is narrowly limited to directors of fisheries in the developing countries, for instance, the enterprise will have failed to capitalize on its full potential and by so doing will probably only perpetuate the myth that a handful of fishery biologists "know what's best" and know how to attain that illusive objective.

The number of fisheries managers who need to be trained world-wide is a very slippery datum to be sure. Obviously determining this number will depend on many factors, not least of which relates to the concept of kinds of jobs and areas of employment, such as that sketched out in Table 3. However, one knowledgeable specialist has bravely attached numbers to the training requirement, and arrives at a total figure of 5 000 individuals, "spread across the countries of the world ... slightly less than one person per million of the world population ... (this) should be considered the minimum"6/. His figures are reproduced in Table 4.

6/ R. Hart, "Towards a Better Understanding of the Management and Development of Fishing Zones" (Table 4)

Table 3

Jobs and areas of employment

Kind of job	Area of employment
Managers of research	Fisheries ministeries Science and technology staffs (governmental) Research laboratories (governmental and university) Natural resource/agriculture ministeries
Regulation/enforcement units	Fisheries ministries Coast guards/navies/paramilitary units International bodies (commissions and others)
Programme managers in loan- or grant-making organizations	International banks Foundations National (public and private) banks International civil service
Planning and evaluation units	Central planning offices Budget bureaus and staffs Fisheries ministries Natural resources staffs
Private business/entrepreneurial	Construction firms (related to shore-based investments) Fishing associations Suppliers of boats, gear, and sundries Processing and distribution companies Parastatal or quasi-governmental bodies or authorities

Table 4

The training requirement (one view)

200	Legal Officers in government departments or universities
200	Directors and deputy directors of fisheries
400	Resource managers
200	Fisheries economists
200	Fisheries statisticians
200	University faculty members in related international studies
100	Officers from regional fisheries institutions
2 000	Students in colleges and universities (ocean sciences)
1 500	Middle management personnel in fisheries departments
5 000	Total training requirement worldwide

Source: R. Hart, "Towards a Better Understanding of the Management and Development of Fishing Zones", Ottawa: Fisheries and Environment Canada, Fisheries and Marine, 7 February 1979, p. 7.

One might quibble with the components of this estimate (I for one have difficulty seeing the need to include 2 000 students in ocean sciences within this specific requirement). However, if a broad definition of the fishery management task is applied - certainly one broader than Hart's - the total figure of 5 000 does not seem all that unreasonable. What proportion of this total should be considered the direct responsibility of the IIFM is another matter entirely though.

4. PURPOSES TO BE ACCOMPLISHED

Let us look at the problem from another perspective: that of the purposes such an institution should be expected to fulfill.

In the most general terms, an IIFM would be created to provide quality level instruction for the present and emerging cadre of fishery managers throughout the world (important to note, but not especially significant operationally). Additionally, efforts to share an understanding of the complexities of the man-fish system would be made to include both policy-makers and key decision-makers whose actions bear on the use of the fishery resource (self-evident, but essential).

More specifically, participants in the IIFM must learn to be aware and sensitive to the full complexity of the economic/social/political decisions that they are likely to be called on to make; the dynamic nature of the fishery resources and their management; and the diversity of participants, interests, actions, and objectives that will be impinging on their particular areas of responsibility. This is more helpful and calls to attention course preparation in many of the key social sciences, a systematic perspective of problems, practical political matters, and a concern for tailoring the educational product to specific areas around the world, e.g., a consistent and appropriate criticism of CIDA/FAO/CECAF Seminar and Workshop series, which in virtually all other respects drew positive reactions from its West African participants, is that there were insufficient cases and examples drawn from the particular areas of African responsibility.7/

It is clear that those enrolled in IIFM must be introduced to a variety of management tools and techniques that have been and will continue to be essential to the proper discharge of their duties and responsibilities. In this regard, the concept of "most appropriate technology", including management technologies, must be stressed. It makes very little sense, for instance, to train someone from a desperately poor nation the intricacies of linear programming models when in actuality his job requires mathematical sophistication no greater than simple statistics, including an ability to collect the data to be analysed. Likewise, what does one really need to know about financial and investment theory and practice generally, and how does this knowledge have to be modified to suit the case of the often fragile, unpredictable, and ever-changing fish resource? How does one devise enforcement procedures that work, and do so with a minimum of administrative overhead and headaches? What instruments of control exist, beyond the often unsatisfactory resorts to subsidies, investment incentives, and brute force policing, that would allow the manager to get the best use of his resources over the long term?

The training emphasis must be on creative applications of very ordinary techniques and technology - all with a keen eye on the practical realities of many of the poorest nations in the world. First and foremost, a philosophy that there may be no simple solution, or no best or optimal solution, to problems must be fostered. The problems are extraordinarily complex, have defied solution in some of the most sophisticated environments in the world, and will contain more uncertainty than most theories and methods of analysis would allow. This is a harsh world in which there appear to be more ways to fail than to succeed. That is, the reality and faithful presentation of that fact must be a central function of the IIFM.

All is not hopeless, however; and we next turn to some measured recommendations for options that an IIFM could consider.

7/ Louis Gaetan, Report on CIDA/FAO/CECAF Seminars and Workshops, 5 July, 1978 (various in in series) (no place of publication, assumed to be published and held by FAO, Rome)

5. CONCEPTS AND CRITERIA UNDERLYING IIFM

Several key facts about the educational environment in which the IIFM would operate need consideration.

The number and likely production of bona fide experts in all relevant aspects of fisheries management is small and not likely to increase, respectively.

Husbanding this talent will be a high priority consideration in the creation of the training programmes of the Institute. It is simply not realistic, nor should one expect, the most highly talented and credentialled fisheries specialists to devote more than a small fraction of their precious time to actual training, despite the fact that the training needs are so vast. We must be creative about when and how the most skilled individuals in this profession are brought within the Institute's programmes.

There are few texts and even fewer teaching materials suitable for the training tasks envisioned for the Institute.

Certainly, there are textbooks on aspects of fisheries, and many of these would be essential departure points for the construction of a training curriculum for fisheries managers. The difficulty with simply taking and using the source materials at hand is that most have been designed for purposes quite different than those envisioned for the IIFM; furthermore, most presume a level of technical specialization and preparation far in excess, in details, of that presumed to be necessary for satisfactory or effective fishery management. Being a competent fishery biologist is a different undertaking than becoming an effective manager of the fish resource.

A handful of training programmes aimed at fishery management exist around the world, but these are small-scale and somewhat limited in scope as compared to the total need.

It will be essential to include the collaboration of all the training personnel located within these programmes. Many can be identified, e.g., in Canada, Dalhousie University; Malta; the London School of Economics; ocean management centres in the United States at several universities; fishery research laboratories around the world. An operating concept of the IIFM is to recognize these other training programmes, to value and bolster them so as to train specialists of many kinds. However, one senses that overall coordination of effort is slight or missing, and a well designed IIFM could perform an important and constructive role of concentrating these resources for the common benefit.

Problems faced in one fishery will, in various guises, have a high probability of appearing in other settings. Successes realized in one fishery, by the same logic, will have a better than random opportunity to be transferred to other places.

The concept here is simple: Preventive management. The curriculum of the IIFM should be problem-oriented and stress real situations, real management solutions, and real successes and failures. The development of training cases, based on this empirical body of knowledge, will be a prime function of the IIFM. Such cases, furthermore, will be best shared and disseminated to other teaching and training institutions - those concerned with fisheries as well as to those having an ancillary but discernible interest in fishery matters, e.g., business school courses in international investment and finance; international law courses in law schools; and courses in international relations, public administration, and economics more traditionally conceived and defined.

Decision-making is a dynamic concept, exemplified in the notion of "decision-making" and "fishery management" processes. (See sec. 3 of Final Report.) The curriculum ought to be designed around such a concept so as to involve and expose the student to the fullness of decision impinging on the world of fisheries.

Elsewhere, the concept of a management or decision process - as related to fisheries and more generally - has been spelled out.[8] This exercise will not be repeated here, other than to point out the organizing and integrating strength of such an orientation to the management tasks confronting those responsible for fisheries. The possible benefits that one expects to follow from a process view are recapitulated in Table 5.

Table 5

Possible benefits from the conception of a decision-making process

Phase	Possible benefits
Initiation/Invention (Define Objectives)[a]	Recognition of problems Creative thinking about problems Prototypical design Crude hypothesis testing Preliminary investigation of concepts
Estimation (Define Units) (Collect Data) (Extract and Interpret Data)	Scientific examination of likely impacts and outcomes of plausible options Normative/evaluation examinations Development of outlines of a complex policy, including programme details Appraisal of claims of key participants Development of performance indicators Specification and estimation of key parameters
Selection (List Options) (Formulate Action)	Focus of debate on actual issues Allowance for political compromises Realistic choice among programme designs and options Reduction in uncertainties about options
Implementation (Execute)	Development of rules, regulations, and guidelines for action Development of specific pieces of programmes Establishment of performance standards, based on previous estimates Minimization of execution costs
Evaluation (Evaluate)	Comparison of estimated and expected performance levels with those attained Assignment of responsibility and sanctions
Termination	Determination of whether the problem is chronic, recurring, or resolvable Generation of information about new problems created in termination acts, some of which may require planning, political attention, and treatment

[a] Actions in parentheses correspond to Tasks described in sec. 3 of the Final Report (Fig. 2)

[8] Part 3 of this Report and Garry D. Brewer, "Managing Fisheries: Some Design Considerations", FAO Circular Nº 718, Rome, December 1978, pp. 85-106, at pp. 100-103

With the exception of the selection phase, there are few, if any individuals or institutions who are primarily concerned with the other five phases of the process. Problems have been identified, usually by individuals who have studied and become concerned about the aimlessness, inequity, ineffectiveness and consequences of the *ad hoc* policies and programmes found at various times throughout the world; however, these cries of alarm have been neither numerous nor have they been acted on with a fraction of the energy and resources needed to "make a difference". Initiation and invention, in short, have been sporadic and unconnected from the sources of power and wealth which could and should have been galvanized to make creative and useful decisions. Estimation, that is scientific efforts to understand the actual environment of fisheries including the creation of plans and options to improve matters, has been undercapitalized and neglected, especially with regard to differentiating between scientific and management information. Implementation has not been ignored, but rather, has been left to a bewildering array of offices, commissions, agencies, and authorities, and the results have been far from satisfactory; this is the reality, and any training programme should work diligently to convey the full complexity of the implementation setting. Few examples of systematic, comprehensive and scholarly evaluations of the world's fisheries exist; this piece of the process is at best embryonic; and sensitizing the would-be managers to the need and importance of evaluation must be a central feature of any training programme. Termination, including efforts to modernize and replace inefficient fishing practices and to cushion local fishing industries from the vagaries of fluctuations in abundance and the market-place, has not even been considered, much less institutionalized in a responsible way. It is, in essence, a "brand new" managerial responsibility.

This perspective of a general management process focuses attention on areas of understanding and action that are central to the working environment of any fisheries manager. These must be central features of any training programme.

Criteria to guide the allocation of time and attention within the IIFM curriculum can be generally deduced and specified.

First, the curriculum must be designed to acquaint students with the variety of professional tasks they will be called on to perform - with full attention to the problems and processes found in the real world of fishery management (e.g., open access, extended jurisdictions, and so forth).

Second, the curriculum must aid the student in understanding the various participants and institutions that have an impact on fisheries. One can imagine that this criterion would be fulfilled by the development of a variety of management "models" - neither simple in nature, nor formally defined. In fact, these models would be deliberately complex and imprecise, sentiments in keeping with the "no best or single answer" concept proposed earlier. Furthermore, the models would be understood in terms of particular examples, not as formal statements or absolutes. The emphasis on real-world cases and examples easily follows from this.

Third, the curriculum should spend a great deal of time helping students learn how to pick out and order facts of a particular situation that are relevant to the completion of professional assignments. What works and why? What fails and why? Where does one turn for necessary professional assistance and guidance? How does one learn to identify what is truly relevant in a particular setting, and then amass the necessary unformation in ways that lead to effective decisions about "what to do?"

Fourth, the curriculum would introduce students to the tools at their disposal (Table 2). While not offering standard or textbook solutions, the curriculum ought to inform the students about these tools and methods of intervention and provide guidance about how best and most realistically to use them. One envisions a situation where most managers will be making do with very little; expensive and scarce resources, such as research vessels and trained laboratory personnel, may have to be "borrowed" or "rented" for short periods of time, rather than creating inflated and wasteful demands to supply every nation with its own exclusive assets.

Fifth, the curriculum should allow the students to make, or at least practise making, complex managerial calculations in a controlled setting - the effects of which would be assessed and correctives suggested. Problems for the real world and case materials that invite proposals for decision would, by this criterion, be central. The basic assumption is that a good way of reaching recommendations in a very difficult situation may be to try out, in a limited risk environment such as a business or management game, a variety of suggestions and then check to see if there is anything obviously wrong with the proposed solutions. By going through this process while under pressure from faculty and other students, the neophyte manager may build up a capacity to propose imaginative and persuasive solutions to particular professional problems.

A distinctive orientation of this curriculum is its desire to teach people how to use data, information and knowledge in their professional assignments. Specifically, it is intended to train people to make informed professional judgements about how complex, even "messy", systems operate and will behave amd what intervention (tools) can be brought to bear to reach reasonable decisions.

6. PROPOSALS

While discussion about any of the following recommendations is in order, and may improve their shape and substance, a sense of urgency dictates that specific steps be taken as soon as possible. These proposals are not the only ones imaginable; they do appear to have much to commend them, however.

6.1 Senior Level Course

It is recommended that a three-day, twice per year, seminar and conference be sponsored and run by FAO for top-level officials and experts concerned about the world's fisheries. Such a course would involve the preparation of lectures and tutorials, as well as actual case materials, by the most qualified and talented experts around the world. All such presentations would be video-taped and full texts, back-up, and supplementary materials would be prepared in "teachable" packages. Besides periodically assembling the most senior officials and experts in fisheries, a desirable eventuality in its own right the senior level course would also allow the collection and preparation of teaching materials for subsequent use (including self-administration) in middle and lower level programmes of instruction. This provision recognizes that the pool of expertise is small and its impact must be multiplied to attain greatest benefit.

This course would concentrate on "core" and general topics of interest, such as the practical implications of the UNCLOS and other standard fishing agreements; cases prepared and designed to demonstrate the interconnectedness of the economic/political/social setting of the man-fish environment; and scenarios and studies that could portray different strategies for the development of a fishery resource - ample attention to disaster and worst case examples should be allotted, too.

Attendance at this course would be by invitation and limited to something on the order of 50 students at any one time. Repeat attendance would be encouraged if the situation dictated.

6.2 Regional/Local Course

Using core materials developed for the senior seminar or course, two to three FAO-based teachers will collaborate with local and regional fishery administrations, authorities and educational institutions to "tailor-make" a one-week course of instruction for the most influential decision-makers at the local and regional levels. Twelve presentations, that is, about one every third week, will be made annually. The intent of this course is to sensitize those having relatively great power or influence over the fishery environment to be aware of the system's fragility and complexity. Accordingly, courses emphasizing the legal and political dimensions of the problem would be highlighted, as would specific cases drawn from

the experiences of the regions in which the regional/local course is presented. A class size of about 50, once again, appears to offer the best trade-off between manageability and a return on the investment and presentation costs for the course. In addition to the FAO contingent, one would expect that some five to six local instructors would be needed to fulfill teaching and administrative obligations for this course or instruction.

6.3 Managerial-Level Course

As rapidly as possible, self-contained and self-administered courses of instruction of some four working weeks' duration need to be created (such courses could be spread out over calendar time and interspersed in a working schedule for those unable to allocate an uninterrupted period of time to the task). A high technology version of the working level or managerial course will benefit by using video-tape and other modern teaching methods (this is in keeping with the VITALOS proposal of Canada's R. Hart, noted elsewhere). Preparation of texts to supplement video-tapes will be required to ensure best use by students in non-Western language groups. A second version of this course will be designed entirely as a correspondence course, and will not need expensive audiovisual devices.

Responsible collaboration with concerned local and regional educational institutions will be necessary to make this aspect of the programme successful. For instance, one can envision the course's being administered by a national college of administration, presuming that back-up support from FAO was given. As a result, successful completion of the course could be credited to the student's professional and academic records in his own country - a matter of some consequence in many areas of the world where education is instrumental to professional and personal advancement. Furthermore, one would expect that the necessary audio-visual support would either already be in place or could be justified and used more generally within the national administrative college setting - rather than justifying the costs of acquisition solely on the basis of the fishery management training programme.

A prototypical model for this version of instruction exists in many of the military services around the world, wherein extraordinarily complex subject matters are routinely taught through the correspondence medium. Consultation with, for instance, correspondence school officials responsible for one or more of such programmes would be an advisable strategy for those developing the working or managerial level course.

Course content and curricular matters are taken up momentarily.

6.4 Fishery Management, Advanced Training

A two-pronged strategy to provide sustained and intensive managerial training for the emerging elite of world fishery management is recommended. The creation of a prestigious FAO or United Nations Fellowship is integral to this strategy.

First, the selection of some 25 FAO Fishery Management Fellows is recommended. Such fellowship would be competitive, with judgements about individual candidates to be made annually by a panel of bona fide experts based on recommendations, statements of performance and achievement, and the needs of the fishing nations of the world. The fellowship is meant to confer status and respect as well as providing tuition and a living stipend for the beneficiaries. During the first year of this two-year programme fellowship recipients will be enrolled in fishery and ocean management professional training programmes around the world, e.g., Dalhousie, the University of British Columbia, Malta, the London School of Economics, and several American universities (Rhode Island, Delaware, Washington), where they will earn a master's degree, or its equivalent, in fishery management or a nearly related field. During the second year (depending on need and capability) the 25 FAO Fellows will be posted to FAO/Rome and/or located within international fishing authorities around the world as working-level, wage-earning interns. Under supervision, candidates would be expected to conduct an independent project, comparable in scope and difficulty to a master's level thesis. The overall training objective of this element of the total Institute programme is sustained exposure to the world dimension of the fishery problem and

also the acquisition of in-depth technical skills that are nor easily obtained within the scope of the shorter term top level and managerial training programmes.

Funding for this programme would be considerable, but creative arrangements with the financial institutions and governmental authorities concerned with fisheries could be imagined and need to be pursued with diligence. For instance, matching grants with the sponsoring nation of the student/fellow may be one source of support; they will, after all, contribute to the human capital of their own nations by virtue of the programme. An endowment fund, derived from a one-time contribution of the World Bank and other developmental authorities could be another source. Portions of the living stipend could be legitimately derived as wages for services and work rendered by the interns, in whichever agency they are assigned to in the second year of the programme.

6.5 General Management, Advanced Course

As a result of performance in one or more of the other fishery management courses, or because of special aptitudes or other considerations, it may be worthwhile to develop a path to a professional graduate degree in management (natural resource management, business administration with a natural resource emphasis, or public administration with a suitable emphasis). The prospect of high quality, continuing graduate education may very well be held out as an incentive to those involved in other aspects of the fisheries management training programme. For instance, honour graduates of one of the various courses could be nominated and selected for advanced management training as their circumstances would permit, with a stated obligation on the individual's part that he or she will indeed return for a period of time to work directly in fisheries management. One could imagine ten to fifteen students per year availing themselves of this element of the overall training programme. In fact, the United Nations University, were it to come into being, could even offer some potential in this regard. Financial responsibility for the students would reside with their sponsoring government or institutions in the case of private sector applicants. FAO's role would be as an intermediary and facilitator, helping to locate the right programme in accordance with the requirements of the individual and his sponsor.

6.6 Special Seminars/Targets of Opportunity

Specialized, tailor-made courses in each of the management topics treated in the core, and other programme modules (to be discussed in the next section) should be considered. These courses would be held from time to time on an *ad hoc* basis in individual countries and/or regions in which fishery problems are central. For example, one might organize and run a special seminar for investment or development bankers to sensitize them to the peculiar characteristics of financial matters in the fisheries business. Intervention, of an *amicus curiae* variety, may be entertained in instances where contentious fishery problems have failed to yield to conventional matters of redress. The flexible nature of this phase of the overall training programme should allow the best use of advisory personnel in the presentation, case preparation, and other aspects of the programme. This confirms well with the overall design criterion to keep administrative and programme overheads to a minimum; it also aligns nicely with the concept of making best possible use of scarce expert talent. Selected video-tapes from the core programme could, depending on the purpose and intention of the seminar, be used as well. Additional potential topics for this kind of activity are numerous: science and research practicums for those involved in stock assessment and regulation; public relations programmes for fishermen and others embroiled in conflicts about specific features of a local resource management programme; recreational and commercial interactions and interrelationships, and many others.

7. THE CURRICULUM

The proposed curriculum is designed in accordance with the Fishery Management Process. However, for planning purposes, this process is recast somewhat to reflect different management styles that are required.

7.1 Management Styles

Preventive Management captures the ideas that some problems confronting a manager can be recognized and anticipated. If done successfully, preventive management can have many worthwhile results: problems managed without undue resource expenditures or without their having reached crisis proportions. Indeed, as is the case with preventive medicine, success with this style of management is marked by the absence of difficulty or crisis. Planning, monitoring and forecasting critical indicators in the environment, and other like endeavours all relate to the concept of preventive management. Preventive management concentrates on the two phases we have called "Initiation/Invention" and "Estimation" (Table 5) and features the operational tasks of "Defining Objectives and Units", "Collecting Data", and "Extracting and Interpreting Data".

Active Management refers to the making and executing of decisions. In other terms, it relates to operational steps taken to "List Options" and "Formulate Actions", including the means used to arrive at choices about what to do. Furthermore, it embraces the full range of activities undertaken by a manager to see that the decisions are put into effect.

Reactive Management contains the idea that the managerial function is not one of simply putting decisions into action, but rather there are continuing responsibilities to assess the effects and impacts of those actions in the specific setting where taken - and to take appropriate steps to ensure that the actions are doing what one expected and intended. Where these conditions do not hold, active managerial remediation would be expected to follow. Among other possibilities, the need to terminate actions may be indicated, and if so, this may necessitate a recycling through the management process to anticipate and accommodate the problems generated by the termination act itself. The concept of reaction underscores the fact that prior to decision empirical facts about the effects of one or more acts are, by definition, simply not known. Only after decisions are executed and measurements of their consequences are assembled can one determine which acts have had what effects and whether or not decisions taken were good or appropriate ones. This is a terribly important idea, particularly in the fishery environment where uncertainties abound and the chance of miscalculation and misimplementation is high. Reactive management, in this sense, emphasizes the need to limit the damage done through well intended but ineffective, or even harmful, interventions

These three distinctions in managerial style are the basis for the curriculum.

7.2 Modules of Instruction

Module 1: Overview - The Complex World of Fishery Management

a. History of the world's fisheries.

b. The present context, including attention to the major participants, their goals, perspectives and actions.

c. The constraints: agreements in force, how various provisions have worked to structure the fishery problem in locations around the world, resources available for management.

d. The stakes: the present and anticipated value of the fish and fish products; the nature of past and likely future conflicts centred on fishery disputes, dimensions of the world food problem and the role of fish as a source of protein and sustenance therein.

e. System problems: What is the nature of current and anticipated problems? What is the likely course of events in an un- or mismanaged world?

f. The challenge: What kinds of solutions need to be created to avert the problems and crises envisioned in the absence of enlightened and effective, worldwide action?

g. The modern fishery manager: concept, responsibilities and tasks.

Module 1 forms the bulk of topics to be treated in the senior level course and, when supplemented with specific materials germane to the areas in question, will be useful in structuring materials for the regional/local course as well. It is essential that basic definitions and understandings of fisheries problems - covered by materials presented in Module 1 - be presented as expertly and consistently as possible. The use of the world's most knowledgeable individuals to do so is self-evident.

With respect to the topics and materials considered for Modules 2 through 5, the following internal organizing principle holds:

Overview of the topic or subject matter
Participants involved or having a stake
Common problems encountered
Theories and concepts available to manage those problems
Methods to do so
Cases/experiences
Resources, including individuals and institutions, available to help one in realistic settings

Module 2: Preventive Management

a. Planning:

i. General theories and concepts about planning.
ii. Strategic and long-range planning: public and private.
iii. Planning information systems.

b. Monitoring and surveillance:

i. Intelligence collection: methods and resources.
ii. Interpretation.

c. Systems and systems analysis:

i. Concepts and objectives.
ii. Methods.
iii. Practice.

d. Research and development:

i. Innovation theory and practice.
ii. State of the art technologies.
iii. "Most appropriate" technologies.

Module 3: Active Management

a. Analysis and the use of expert and consultative talent:

i. The role and purpose of experts.
ii. Representative kinds of expert information found in fisheries.
iii. The distinctions between "science", "analysis", and "politics" (decision-making).

b. Biological models and approaches:

i. Concepts of population dynamics (growth, mortality, yield, biomass).
ii. Effects of fishing on stocks (models).
iii. Effects of exploitation patterns on yield, variability, and catch rates.
iv. Estimation and projection.
v. Fishing plans, shared stocks.

c. Economic models and approaches:

i. Micro and macro economic theory.
ii. Economics and marine policy.
iii. Regulation theory.
iv. Natural resources economics.
v. Development economics, including food and agricultural economics, demographics.

d. Financial and investment models and approaches:

i. Financial management.
ii. Investment: theories of value, methods of analysis, financial instruments and institutions.
iii. Subsidies and infant industries, including forms of protection.
iv. International trade (fishery emphasis).

e. Environmental models and approaches:

i. Evolutionary and behavioural ecology, including community structure.
ii. Environmental theories and practice.
iii. Weather.
iv. Ocean dynamics.
v. Multiple uses of resources.

f. Operations research models, methods, and approaches:

i. Statistics and data analysis.
ii. Mathematical models in management science.
iii. Operations analysis, including linear programming, network analysis, probability, gaming and simulation.

g. Political models and approaches:

i. Interest groups, including elites.
ii. Decision-making.
iii. Bureaucratic politics.
iv. Bargaining in international relations.

h. Legal models and approaches:

i. International fishing regulations.
ii. Property and other rights.
iii. Environmental protection and legislation.
iv. Joint and multi-party ventures and agreements.
v. Transit rights and regulations.

i. Administrative models and approaches; general:

i. Institutions as resources: FAO, UNDP, World Bank, commissions, agencies (related to fisheries).

ii. Management models found around the world; structure, function and practice, (e.g., marine, coastal zone).
iii. Budgeting and fiscal control.
iv. Personnel management.

j. Administrative tools of the trade; specific:

i. Licensure.
ii. Taxation.
iii. Access limitation.
iv. Enforcement.
v. Regulation.

k. Public affairs:

i. Marketing.
ii. The press and other media; public education.
iii. "Participation": hearings, public meetings and relations with politicians.
iv. Negotiation and meditation.

Module 4: Reactive Management

a. Evaluation Research:

i. Process evaluation; internal auditing, accountability, control.
ii. Response evaluation; assessing the operational effects on the organization as a result of external demands, threats and opportunities.
iii. Impact evaluation; effects of management actions taken on the decision setting, sanctions, corrective actions, responsibility.

b. Termination:

i. Strategies and concepts; the politics of termination, indemnification and compensation.
ii. Tactics; insurance, savings banks, receiverships, trust offices, salvage specialists, escrow brokerages, welfare, retraining, and resource reallocations.

Module 5: Specialized and Advanced Topics and Problems

(To be determined on an *ad hoc* basis, but will rely on specific elements contained within Modules 1-4 as "building blocks".)

7.3 Illustrative Course Descriptions

To give one a better idea of what various topics in the curriculum might look like, a few illustrative course descriptions are next presented.

Strategic Management Planning: (A course in the Preventive Management Module 2.a.) This course focuses on emerging research and experience in the process of producing long-range plans (strategic, or about five years in the time horizon); emphasis is placed on the management problems encountered in plan execution. The course reviews and evaluates various concepts of long-range planning and various documents and formats used in the planning process; it determines the kinds of analyses required to prepare a strategic plan; it develops various strategic models appropriate to realistic situations and analyses common problems encountered in their execution; and, finally, it assesses actual plans found in several fishery settings. Students are required to prepare a strategic plan relevant to their own working situation, and such plans will be presented for discussion and criticism by other students and the instructor.

Operations Research: Data Analysis and Statistics: (Module 3.f.i.) This foundation course in methods and techniques is intended to teach the student how to use statistics to extract information from data, which can then be used for policy and research purposes. Use of actual fisheries data will be emphasized, as will exposure to statistical analyses undertaken and used in fishery settings around the world.

Economic Analysis: (Module 3.c.i.) This course concentrates on the role of markets in determining the opportunities facing individuals, firms, and institutions. Also considered are the policy issues facing fishery managers and related public officials as related to resource allocation patterns found in various economic systems, especially as regards market deformations created by open access provisions. Topics include analysis of competitive markets, firm behaviour, and the theory of profit. Consumer behaviour, welfare, and the problems of economic policy design are also treated.

Managerial Accounting and Control Systems: (Module 4.a.i.) An examination of appropriate accounting information systems for purposes of internal decision-making, performance evaluation and control. Topics include alternative cost classification schemes and their impact on decision-making, budgeting, responsibility accounting, and other selected issues.

Finance and Investments: (Module 3.d.i. and ii.) A study of financial institutions and instruments affecting the fishery setting, with emphasis on theories of value and methods of analysis. Financial practices are examined with respect to law, international trade, taxation, and development policies and programmes.

Fisheries Policy Analysis: (Module 3.a.) Develops techniques of management and policy analysis in fisheries settings and integrates these via the case study approach. The course is meant to provide institutional information as well as vicarious experience with the policy development and management problems encountered by fishery managers. Cases concentrate on alternative management systems, decision-making, technology, and organizational design. Concern for the international, national, regional, and local dimensions of the problem will be emphasized. The role and effective use of expert and consultative talent will also be treated throughout the course.

These illustrative courses represent an introductory level of coverage and exposure suitable for all students in the regional/local and managerial courses. All such students will take at least this level of instruction to ensure breadth of exposure and coverage. In addition, in-depth exposure will in time be provided through concentration and elaboration on individual topics found within any one of the modules. For instance, for individuals concerned primarily with environmental protection as relates to fisheries, there might be a course developed to expand Module 3.h., "Legal Models and Approaches", to allow extended coverage and concentration on environmental protection legislation, regulations, and enforcement. Obviously, at least in the early stages of the IIFM's development, certain topics will have relatively higher priority for in-depth treatment. Module 3.j. "Administrative Tools of the Trade; Specific", is a good case in point, given that it treats licensure, taxation, access limitation, and the like - all important topics for many fishery managers.

One might react to the curriculum proposal by trying to dismiss some "apparently" less important segments of it. For instance, who really needs to know anything about marketing or negotiations? While in any specific instance this demurral may have force, the burden of proof rests with the complainant. In the past, fishery managers have suffered from too narrow a preparation and too limited a conception of their role and responsibilities, features that can only worsen under the anticipated changed conditions of fishery management in the coming decades. This curriculum is self-consciously intended to broaden the exposure of the would-be manager, at the very least by acquainting him with important, often neglected, aspects of fishery management. Specialization will come soon enough through on-the-job experience.

7.4 Case Examples

Cases used in the curriculum should generally be based on actual situations or likely problems that will confront the manager. They should, furthermore, stress a multi-disciplinary approach to problem solving.

For instance, a consistent and difficult problem concerns what should be done to dampen the effect of economic and biological fluctuations, especially as relates to a specific fishery. The North Sea herring is in a drastically depleted state. Were there early-warning indicators that could have led to preventive management actions? If so, what are these, who paid attention to them, and what initiatives could and should have been invoked, by whom, to avert or reduce depletion of the stock? If not, why not and what might be done in the future, in this and other fisheries, to gain advance warning? Who should be doing it? How should it be done? And so forth. With respect to the herring case, what compensatory and remedial steps have been taken to reduce the economic and social impacts of depletion? What about insurance programmes to allow herring (and other) fishermen to bank some portion of their receipts during normal or peak years in anticipation of down-turns? Are there programmes to reconfigure and refit boats to fish different stocks and what will happen to them? What about more drastic remediation, such as welfare, retraining, and relocation?

Capital markets are notoriously insensitive to the complex needs and realities of modern fisheries. Investments are neither as well considered nor are they as well tuned to the vagaries of the fishing setting as they must eventually be. Using a case of an apparently over-capitalized fishery, e.g., Mexican shrimp or trawling in the South China Sea, what can be learned about the effects of investment decisions made worldwide on specific fisheries? Would it, for instance, make sense for regional development or national banks to offer investment capital for fisheries at rates that allow in time, control over a proportion of the fleet? If so, this might add a degree of management control sufficient to reduce pressure on a specific stock in a given location.

Research and development related to the creation, introduction, and diffusion of new technologies can be demonstrated well via the case study mechanism. Are there better and less expensive ways of fishing stocks which at present are not economically attractive (fuel costs feature prominently here)? Are these measures appropriate for other locations? If not, are they adaptable? Research and development cases could illustrate that the most modern and up-to-date fishing practices do not necessarily produce the largest net social (or even economic) benefits. Indeed, a great deal of thought and attention should be devoted to the elucidation of technologies appropriate for specific circumstances.

"Success stories" need to be made known. Where have managers been able to find a workable and successful mix of programmes, strategies, and tactics? Are these lessons generally applicable, applicable with slight modification, or unique? If generally applicable, the case study should stress this. If modifications need to be made, then these should be high lighted and this message disseminated. If unique, a cautionary lesson is dictated.

Joint use of resources, in which the development of a fishery necessarily means that some other use of the commited land, capital and human talent is foregone, will provide many rich examples of the complex interactions that exist between biological, economic, political, and social features of the decision environment. Even within a strict definition of "fishery", some significant problems could be illustrated. With respect to the mix of fishing practices encouraged or actively promoted by a fishery manager, determining whether commercial, recreational, sport, or artisanal fishing means should exist, and in what proportion, may be critical. In a specific locale, is it better to promote a sport fishery, with attendant heavy investment in the infrastructure needed for tourism, or can the society in question benefit more by highly efficient commercial exploitation of the available stocks? Might the protection of an artisanal fishery, with its often inherently

picturesque aspects, be made an integral part of a larger sport fishing based tourism programme? Especially for many of the underdeveloped, semi-tropical regions of the world, such mixed fisheries appear to have much to recommend them.

Realizing that most management schemes have associated costs can be stressed through case presentations, too. More than just the immediate, direct costs of putting a plan or programme into action, the student should be made aware of the related and continuing long-term costs, e.g., enforcement or regulation, and of the many non-quantifiable or non-monetary costs that may derive from a management regimen, such as the social costs of an ambitious development programme or the international relations implications of changed fishing practices, especially with respect to stocks shared by two or more nations.

8. IIFM PUBLICATIONS SERIES

To provide continuity, up-dating and coordination of its professional programmes, the Institute is advised to consider creating several complementary publications, each having a somewhat different purpose.

Foremost is a professional journal, whose purpose is captured in its title: World Fisheries Management. A quarterly publication of the Institute, this is intended to be the "journal of record" for the profession. Besides rewarding excellence in management and research through publication recognition, the journal would have the additional effect of creating professional norms and identifications that are presently lacking.

A second series would be a "Who's Who in Fishery Management". All Institute graduates would of course be listed. Furthermore, the volume would collect in one place a description of the human resources available worldwide that could be called on for assistance in specific settings. Such a publication has not been necessary until now because the number of involved individuals has been small. This will undoubtedly change dramatically in the coming years.

"Research Issues and Findings" could be abstracted and disseminated in "tear sheet" form to all graduates of the IIFM. The idea here is to provide timely notification of important research in a handy, usable format so as to gain the attention and appreciation of busy managers. As it stands, research relevant to fisheries (broadly construed, as we have done it here) is spread over dozens of specialized journals and publications, with the result that no one individual could be expected to keep current. This series would serve the purpose of drawing much of the diffuse research product together and presenting its salient points briefly and in a uniform style so that the manager can then decide whether or not to follow up by obtaining and reading the complete documents from which the abstract has been drawn. The series could be catalogued according to the modular subject matter headings proposed for the IIFM's curriculum.

A companion series featuring legal and regulatory matters might in time also be developed.

Case studies will be an important component in the Institute's training effort. Not only will many of the educational programmes be relying on realistic case materials, but there is an unexploited market for such cases in other management educational programmes worldwide. For instance, the Case Clearinghouse at the Harvard University Business School actively solicits public and private management cases and then publicizes and distributes the best of these to hundreds of educational institutions around the world. Having fishery management problems represented in this pool of teaching cases should have positive, but unpredictable, consequences.

9. COSTS (BY PROGRAMME ELEMENT)

Estimating what this proposal will cost is a very hazardous business, and one undertaken with trepidation. Nonetheless, the following "guesstimates" ought to provide at least planning factors for purposes of more intense discussion and modification.

The figures have been derived by considering each of the programme elements in turn and then trying to visualize what would be needed to start up and sustain the various activities associated with each. Estimates of the man-years and related costs for each programme element are thereby made, and all such estimates are totalled and valued in dollar terms by use of some conventional planning rules of thumb or factors. Finally, it needs to be stressed that this is not a lavish or "gold plated" assessment; it could be done for far more, but I doubt that it could be done for very much less.9/

Table 6

Cost estimates

PROGRAMME ELEMENT	MANPOWER REQUIRED Start-up	MANPOWER REQUIRED Recurring	TOTAL CASH EQUIVALENT Start-up (U.S.$ 000)	TOTAL CASH EQUIVALENT Recurring (U.S.$ 000)
Senior Level Course:				
Instructors/Coordinators	4 PMY[a/]	4 PMY		
Consultants	5 PMY	1 PMY		
Technical Support	3 TMY[b/]	1 TMY		
Equipment/Supplies			75	25
Travel			75	50
Subtotal	9 PMY	5 PMY		
	3 TMY	1 TMY		
			675	350
Regional/Local Course:				
Instructors				
FAO-based	3 PMY	3 PMY		
Regional/local	5 PMY	5 PMY		
Consultants	2 PMY	1 PMY		
Technical Support	10 PMY	5 TMY		
Equipment/Supplies			100	50
Travel			150	150
Subtotal	10 PMY	9 PMY		
	10 TMY	5 TMY		
			1 000	775
Managerial Course:				
High Technology				
Programme Manager (FAO)	1 PMY	1 PMY		
Technical Support	3 TMY	2 TMY		
Equipment/Supplies			150	100
Low Technology				
Programme Coordinators	4 PMY	4 PMY		
Technical Support	3 TMY	3 TMY		
Subtotal	5 PMY	5 PMY		
	6 TMY	5 TMY	550	475

9/ The author has participated in the start-up and early operations of two, not unrelated, policy analysis and management educational ventures within the last five years: Yale University's School of Organization and Management and the Rand Corporation's Graduate Institute of Policy Studies

PROGRAMME ELEMENT	MANPOWER REQUIRED Start-up	Recurring	TOTAL CASH EQUIVALENT Start-up (U.S.$ 000)	Recurring (U.S.$ 000)
Advanced Fishery Management:				
Programme Manager	1 PMY	1 PMY		
Technical Support	1 TMY	1 TMY		
FAO Fellowships (25 at U.S.$ 50 000)[c/]			1 250	1 250
Subtotal	1 PMY	1 PMY		
	1 TMY	1 TMY		
			75[d/]	75[d/]
General Management; Advance Course:				
Programme Manager	1 PMY	1 PMY		
Travel			50	25
Subtotal	1 PMY	1 PMY		
			100	75
Special Seminars:[e/]				
Programme Manager	1 PMY	1 PMY		
Consultants	2 PMY	1 PMY		
Subtotal	3 PMY	2 PMY		
			150	100
Publications:				
Journal				
Editorial	0.5 PMY	0.5 PMY		
Staff	0.5 TMY	0.5 TMY		
"Who's Who"				
Editorial	1 PMY	0.25 PMY		
Staff	1 TMY	0.25 TMY		
Research/Legal Findings				
Editorial	0.5 PMY	0.5 PMY		
Staff	0.75 TMY	0.75 TMY		
Case Studies				
Editorial	1 PMY	0.5 PMY		
Consultants	3 PMY	1 PMY		
Staff	5 TMY	1 TMY		
Subtotal	6 PMY	2.75 PMY		
	7.25 TMY	2.50 TMY		
			481	200
Totals	35 PMY	25.75 PMY		
	27.25 TMY	14.50 TMY		
			3 030	1 651[f/]

Notes of Table 6

a/ PMY: Professional Man Year, each of which is valued at U.S.$ 50 000, which includes benefits, fringes and allocation for some portion of overheads

b/ TMY: Technical Man Year, each of which is valued at U.S.$ 25 000, which includes benefits, fringes and allocations for some portion of overheads

c/ Assumes endowment of U.S.$ 10 million which, at current rates of return will generate income of approximately U.S.$ 1.25 million/ year. This yields expected cash flow of U.S.$ 50 000/year/fellowship. However, assume that only U.S.$ 30 000 is expended for tuition and stipend for each; this yields a surplus of U.S.$ 500 000 from endowment which can be used to offset partially other costs of the IIFM

d/ Figure reflects only manpower costs of the programme element

e/ Need to explore cooperative arrangements to help offset costs of special seminars in order to make them as nearly self-supporting as feasible

f/ Total of U.S.$ 1 651 000 assumes endowment offset from non-tuition and stipend portion of U.S.$ 500 000/year. (See note "c/")

10. POTENTIAL AND EXPECTED OUTCOMES OF THE IIFM

The primary outcome of the IIFM would be the generation of a corps of trained fishery managers prepared for deployment throughout the world. These managers represent a different professional speciality than any presently existing, and, in time, their capabilities should be recognized and valued by decision-makers and others throughout the world. In this sense, standardization - with respect to outlook, orientation, shared professional norms and expectations - is encouraged, not forced. Any nation that wishes to participate in the programme to attain the benefits of this professional service and talent may certainly do so.

With respect to the core training programmes of the IIFM, it should be stressed that a potential exists to come in contact with a large number of individuals rapidly. Furthermore, due regard has been given to the differential roles that types of fishery managers perform: some are concerned with highest level decisions and problems; others have more detailed and specialized responsibility for selected aspects of the fishery setting. At a respectable cost, it is argued, a large number of critical individuals can be reached, trained, and returned to positions of responsibility - and all within a relatively short period of time.10/

For instance, somewhere between one third and one half of the effort is targeted for the local/regional programme element. This choice reflects an attitude that the key area demanding training attention is on the "battlelines". It stresses the crucial importance of relating general managerial concepts, theories, and tools to specific and realistic settings. And it works to minimize diversity in the background and composition of the class so as to enhance learning. The anticipated yield, in terms of graduates, from this programme is on the order of 600 per year.

It should be noted that a cooperative training attitude is embraced for most programme elements in this proposal. That is, to the greatest extent possible, e.g., through in-kind provision of classroom space, use of local instructors and facilities, local participation

10/ The "recurring", or annual operating cost, once initial investments are made, is approximately that needed to run an American, urban, secondary or high school. This matched against the total need and expected benefits from the IIFM helps place the matter in perspective

is actively sought. A key, and correct, assumption underlying this proposal is that no one nation or collection of nations in a given region should expect the Food and Agriculture Organization (or any other external agent) to absolve them of their inherent responsibilities to train professional managers. Rather, the appropriate idea is one of "helping them to help themselves".

A specific outcome of the proposal, sought in various means, will be the concentration of scarce technical and professional expertise and the coordination of this precious resource on behalf of the world's management training requirements. The senior level course has been structured to this end, as have elements of the publications programme, especially "Case Studies" and "Research Issues and Findings".

On the scientific side, there are potential benefits worthy of note. Through its various programmes the IIFM should be able to help identify and undertake needed research in the fishery area. This is not meant to place the Institute in a competitive position with other, existing research enterprises; rather, it should be seen as a complement and enrichment of these efforts - specially as pertains to scientific endeavours stimulated by a wide range of management as contrasted with narrower biological challenges and opportunities. A problem is no less scientific, at least as regards the methods, theories and approaches taken to understand and resolve it, because it primarily focuses on economic, administrative and political aspects of the fishery setting than one more conventionally defined along biological lines. The Institute will also have a role is assisting and working toward the definition and promulgation of standards for data collection and use; however, once again, the fundamental point that management data and information are not the same as biological ones must be restressed.

Perhaps the greatest contribution of the Institute will be a positive and symbolic one: its creation, existence, and determined prosecution of its various programmes signals the world that fisheries are important, must be managed far better than they have been in the past, and that some dedicated individuals are working hard to realize this goal.

We should hope for nothing less.

APPENDIX 3

FISHERY MANAGEMENT AND FISHING RIGHTS

by

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EXECUTIVE SUMMARY

In the past most marine fish stocks have been exploited as common-property resources. Neither fishermen nor fishing companies possessed any form of exclusive rights to the fish stocks they depended upon. Like other common-property resources, fish stocks have frequently been overexploited and otherwise misused.

The traditional forms of fishery management did not establish fishing rights. While these management policies have sometimes succeeded in preventing the depletion of fish stocks, they have usually resulted in increased overcapacity of fishing fleets and processing plants. Consequently fisheries have become progressively more difficult to manage, and several important managed fisheries have actually collapsed. But in any case, overcapacity has resulted in increasing economic inefficiency.

With the advent of 200-mile zones (EEZs) coastal states now have jurisdiction over major fish stocks. However, unless exclusive fishing rights are established, these resources will probably continue to be inefficiently exploited. The ideal form of fishing rights seems to be a system of transferable fishermen catch quotas, allowing each licensed fisherman (or vessel) to catch and sell specified quantities of certain kinds of fish. Such a system would control catches and prevent depletion, and at the same time overcome the incentives leading to overcapacity.

Alternative forms of fishing rights are vessel licences and effort quotas. These provide a less direct form of control than fishermen catch quotas, but might be appropriate under certain circumstances. Royalties (taxes) of various kinds can also be employed as a component of an overall management programme. The most suitable method, or combination of methods, will depend upon the particular characteristics of the fishery in question.

In international fisheries, national quota allocations may be used to divide fishing rights among the nations involved. Each nation is then in a position to allocate fishing rights pertaining to its quota to individual fishermen or firms.

Introduction

The fishing industry differs from most other primary resource industries in one important respect: unlike farmers, miners, or lumbermen, fishermen do not ordinarily own the resource base from which they derive their income. Fishermen are thus forced to compete for their share of the catch taken from a finite resource stock. As with other "common-property" resources, this competition, if unregulated, leads to an overexpansion of fishing capacity, involving more vessels and greater processing capacity than is required to harvest and process the available catch. 1/ In many instances this process ultimately results in overfishing - i.e., in the depletion of fish stocks to levels below those that produce the maximum sustainable yields. It has in fact become almost axiomatic that the unregulated fishery consists of "too many boats chasing too few fish."

In other resource industries, governments have found it necessary to establish complex systems of restrictions and rights pertaining to the use of the resource stock. In the extreme case, rights are established which are sufficiently exclusive to eliminate competitive use of the resource - this is the norm, for example, in agriculture, forestry and mining. But in many other cases, including particularly water resources, as well as fisheries and wildlife resources, such "sole ownership" rights (i.e., rights which guarantee exclusive use - possibly subject to a variety of ancillary restrictions - to a unique individual or firm) are generally not feasible. In these cases governments may wish to establish alternative systems of rights and restrictions that will overcome the problems associated with competitive exploitation. It is clear, however, that no effective system of rights can be established unless the state in question has jurisdiction over the resource (or at least over a specified portion of the resource).

In the case of marine fisheries, the lack of individual states' jurisdiction over most stocks prior to the establishment of 200-mile economic zones meant that systems of rights could not be readily established. The role of international management commissions was thus almost entirely limited to management procedures that were non-exclusive, in the sense that access to the resource remained unlimited, but that nations participating in the commission agreed to control their fishing operations according to the rules established by the commission. Thus gear restrictions, closed seasons and areas, total catch quotas, and the like were used in order to prevent the depletion of stocks, or to accomplish the rehabilitation of depleted stocks. It is ironic that, although these methods are indeed often successful in preventing depletion, they almost inevitably lead to a further expansion in fishing capacity, and are consequently from this standpoint largely self-defeating. In practice, this process usually manifests itself in terms of a progressive shortening of the fishing season, with the entry of more and larger vessels, which become capable of capturing the annual quota in fewer and fewer days of fishing. When the regulation is by means of gear restrictions, closed seasons, and the like, the resulting fleet expansion will tend to overcome the regulations, which will then have to be revised, initiating further expansion.

The establishment of 200-mile coastal zones has, of course, changed the ownership status for many important fisheries. In principle, coastal states could now grant sole ownership rights to fishery resources to private individuals or firms, or to nationalized corporations. For a variety of historical, social, and political reasons, however, this possibility appears remote in most instances, at least in non-socialist countries. Furthermore, there remains numerous transboundary, migratory, and pelagic stocks which are not amendable to the control of any single state.

1/ In economic terms, fishing capacity is defined to be excessive when the marginal increase in the present value of net economic yields is less than the marginal cost of increased capacity, as perceived at the time when marginal expansion occurred. It can be demonstrated that, if both capital markets and information are perfect, the open-access fishery will experience excessive capacity according to this definition.

The question then arises as to the availability of economically effective techniques of fishery management that do not depend on sole-ownership property rights. This interesting and important question has until recently received only cursory study by fisheries economists and other experts. 2/ The three main candidates that have been suggested as proxies for sole-ownership rights are: (i) licence systems; (ii) allocated catch quotas; and (iii) taxes. These methods clearly have quite different implications for management and for the distribution of economic benefits. Their merits and limitations will be assessed in this study, and will be compared with the more traditional approaches such as seasonal closures, gear restrictions, and the like. Combinations of various methods will also be discussed briefly.

The analysis presented in this paper pertains to fisheries in which fishermen (or groups of fishermen) act competitively in searching for and capturing fish. Fishermen's incomes are determined by the value of their catches, net of fishing costs, and the underlying assumption of the analysis is that fishermen's decisions reflect their attempt to maximize these incomes, subject to current biological and economic conditions and to any imposed regulations or restrictions. We will also attempt to take cognizance of the purchasing-processing sector to which fishermen sell their catches, although this sector is much less likely to be competitive, and is hence more difficult to analyse definitively. In particular, our study does not pertain to the fully planned and integrated fishery (except inasmuch as such a fishery may be based on a stock supporting other, competing fisheries).

Competitive fishing

According to the generally accepted theory of the unregulated "common-property" fishery, vessels will continue to enter such a fishery until an equilibrium situation is reached in which additional vessels cannot enter the fishery profitably. This situation is economically inefficient because the value of the marginal catch (i.e., the increase in total catch caused by the entry of the last, or marginal vessel) is less than the marginal cost. 3/ Of course, additional entry to the fishery may occur later, if the value of fish rises or if more efficient, less costly techniques of fishing are developed. In other words, the "equilibrium" of the common-property fishery is subject to continual readjustment as conditions alter.

Depending on the relationship between the value of fish and fishing cost, this (shifting) equilibrium may occur at a fish population level below the MSY (maximum sustainable yield) population, in which case it is customary to refer to the stock as being "overfished." From the economic viewpoint, however, overfishing occurs whenever marginal value is less than marginal cost - i.e., in every unregulated fishery (see note 3).

Some important exceptions to this standard theory should be noted. First, in cases where fishing requires highly developed technology and associated skills, the limited supply of vessel capital, or of sufficiently skilled skippers and crews may result in barriers to entry which limit the expansion of the fishery. Also, a lack of information may upon occasion prevent outsiders from realizing the full extent of profitability of a certain fishery. In most cases, however, such situations are likely to be transitory, and entry up to the zero-profit level can be anticipated over the long run.

2/ A brief bibliography of recent works relevant to fishing rights appears at the end of this paper.

3/ This principle is stated more precisely, in terms of present values, in note 1 above, and should be further qualified to include consumers' surplus (social value exceeds market value) and producers' surplus (social cost is less than marginal cost) in both the harvesting and processing sectors; see Clark, 1976; Anderson, 1977; Clark and Munro, 1979.

Another important reservation concerns the role of the fish purchasing and processing sector, which in practice often consists of a small number of large firms. A tightly organized processing sector may be in a position to control the price paid to fishermen for raw fish, in which case it may act very much like a sole owner of the fishery. A reasonable level of economic efficiency may result, with most of the profits (or "rent", to use the economists' terminology) accruing to the processing firms. 4/ This situation might again be a transitory one, however, unless government action were taken to exclude entry to the profitable processing sector.

In any case, regardless of exceptions there is little doubt that the history of fishery management has recorded many serious failures. Even in cases where management could be termed successful in biological terms (and these successes should not be underrated, since preservation of fish stocks is an obvious prerequisite to successful economic management), the economic performance of the fishery has often been unsatisfactory, as evidenced by gross excesses of capitalization and correspondingly shortened fishing seasons and increased problems of control. These developments, which are in fact predictable from economic theory, all stem from the failure to resolve the basic common-property issue.

Restrictions and rights

Any approach to the management of a fishery necessarily imposes certain restrictions upon the activities of fishermen. The types of restrictions that have most often been imposed in the past, exemplified by closed seasons, closed areas, gear limitations, and so on, have the property of being non-exclusive, in the sense that all fishermen (existing or potential) are affected more or less equally by such restrictions. Alternative approaches, such as licence programmes and vessel-quota systems, are exclusive: only those fishermen possessing licences or quotas are eligible to catch fish. Such exclusive privileges we shall refer to as fishing rights.

The classification of exclusive vs. non-exclusive restrictions may not always be clearcut. Consider taxes, for example. If anyone is eligible to fish subject to the payment of a tax, then the tax restriction is non-exclusive from the point of view of the fishermen. Clearly, however, some authority must exist that possesses exclusive power to impose and collect the tax. It is this authority that in essence then possesses rights to the fishery. Since rights by definition involve the exclusion of non-participants, rights can only exist in conjunction with some authority capable of enforcement; the use of taxes, quotas, or other regulatory instruments then determines who receives the economic benefits from the resource in question. 5/

At the present time, no international authorities exist which possess rights to marine resources; proposals to establish such authorities have met with uniform resistance by sovereign states. No doubt the establishment of 200-mile zones of extended jurisdiction by coastal states is a consequence of the realization - during the protracted negotiations at the Third United Nations Law of the Sea Conference - that such authorities are not likely to come into existence in the foreseeable future.

Following the establishment of 200-mile economic zones, it appears that the problems of fishery management can be divided into three quite separate classes: (a) national fisheries exploiting stocks that remain within single economic zones; (b) transboundary fisheries exploiting stocks that remain within the economic zones of two or more states, and (c) fisheries of the high seas, which are open in theory to an unlimited number of

4/ Further study, both theoretical and empirical, of the economics of fish processing and marketing sectors is needed (see Clark and Munro, 1979). In practice, a bewildering complexity of financial arrangements between processing firms and fishermen is observed, but these have not been thoroughly investigated.

5/ See Schmid, 1978, for a discussion of the role of rights in economic systems.

countries. Difficulties of management tend to increase according to the classification, as national rights become progressively less exclusive.

The fundamental economic theorem of common-property resources, as applied to the case of the fishery, can now be stated incisively in the form: until some form of exclusive fishing rights has become established, the fishery cannot produce positive economic rent over the long run. 6/ Thus, whereas exclusive economic zones provide coastal states with the opportunity for deriving economic rent from the harvesting of national fishery resources, this opportunity will not be realized until some form of exclusive fishing rights is established. In the case of transboundary fisheries, the establishment of exclusive rights must involve mutual agreement between states regarding the division of the total catch. For high-seas stocks, or highly migratory species, the main difficulty lies in the large number of possible participants. Of course, international agreements do not need to cover all the details of fishing rights: national allocation of catch quotas would be sufficient to permit each participating state to manage its own fishery in an efficient manner.

Types of fishing rights

As noted above, three general classes of fishing rights exist:

(1) licensing programmes
(2) allocated catch (or effort) quotas
(3) taxes on catch (or on effort)

These techniques will now be analysed and compared.

Licence programmes

In a licence programme, specific vessels and/or specific fishermen are licensed to catch fish. In establishing a licence programme, a large number of related issues must be resolved. Which fishermen (or vessel owners) are to be granted licences? Are licences to be granted free of charge, or at a small "administrative fee", or are significant fees to be charged? Will licences be transferable, and if so, under what conditions? Will the number of licences vary over time, and if so, how will this variation be accomplished? Do licences limit the time and place of fishing, species to be caught, tonnage, length, and horsepower of vessels, gear to be employed, etc.?

Apart from these technical considerations, it is important to realize that licensing by itself does not resolve the common-property problem of fisheries. The possession of a licence gives each fisherman a right to compete for the available catch, but (unless accompanied with a system of allocated quotas) does not give the fisherman the right to any actual catch of fish. Consequently each licensed fisherman will be motivated to undertake any action that will increase his share of the catch.

It has in fact been a standard experience following the introduction of licence programmes that licensed vessels have been progressively replaced by larger, more powerful vessels with increased capacity for catching and storing fish on board. Unless such vessel capitalization is specifically prohibited, total fishing capacity may ultimately expand to a level far in excess of the originally licensed fleet, thus thwarting the principle of the licence programme. Competition for the catch may also force individual fishermen to act in other ways contrary to the overall economic efficiency of the fishery. Care in the storage and handling of fish on board may be minimized, for example, with a resulting reduction in

6/ Economic rent is defined as the excess of the value of the catch over the opportunity cost of catching. Forms of economic benefits other than rent, viz. consumers' surplus and producers' surplus, may accrue even in the absence of fishing rights, and these benefits may be largely preserved by management techniques that prevent depletion without establishing rights. Conversely, certain forms of rights (such as monopoly rights or monopsony rights) may result in the reduction of these other benefits (see Clark and Munro, 1979).

product quality. Vessels may be overloaded to dangerous levels before repairing to port. Fishing may take place under unduly hazardous weather conditions. Concentration of the catch over a short season may overload the capacity of processing plants, which will be comparatively idle for the remainder of the year.

While these problems, which are of course particularly typical of the open-access fishery, may be somewhat alleviated by the use of licences, in many cases various additional regulations will be required. The length, tonnage, and horsepower of vessels may need to be controlled. As vessels become more efficient, the number of licensed vessels may have to be reduced. Restrictions may have to be placed on fishing gear and on detection equipment. Fishing grounds may have to be closed at various times to various types of vessels or gear, and so on. Unless very carefully planned and administered, these measures will have a negative effect on efficiency. In order to achieve a reasonable level of economic efficiency, a complex system of regulations may thus be required in conjunction with the licensing programme. The need for complex regulations might be reduced or eliminated, however, if a system of allocated catch quotas were to be introduced. (Various types of taxes could also be used in principle in this regard, and this possibility will be discussed later).

Allocated catch quotas

In principle, catch quota allocations 7/ can be made at various levels. In an international fishery, for example, the total annual catch may be allocated between participating states, a practice that has already been employed in several international fisheries. In a national fishery, the catch may be allocated between various groups of fishermen, according for example to vessel type. Finally, catch quotas may be allocated to individual vessels, or to individual fishermen. At the present time, however, only a few fisheries are subject to a vessel or fisherman allocation scheme.

The fundamental advantage of an allocated catch quota system is that it directly counteracts the undesirable competitive features of the common-property fishery. Quota allocations are in fact a normal technique used in the management of other common-property resources that cannot readily be divided into appropriable units - examples include water supplies, common grazing lands, etc. The owner of a quota knows that (barring unforeseen circumstances) he will be able to take his quota regardless of the activities of other users. On the other hand, he is prohibited from exceeding his quota. With this knowledge, it is then to his benefit to exploit his quota in the most economically efficient manner. 8/ The main incentives for wasteful expansion of fishing capacity and other inefficient activities are thus eliminated.

In view of the economic advantages of fishermen's (or vessel) quotas, it may seem surprising that they have not been extensively employed. The necessary exclusive national jurisdiction over fish stocks is, of course, only a recent development, and the transition from unlimited free access to a system of exclusive rights can hardly be expected to materialize overnight. Both fishermen and administrators may properly take a conservative view of new management systems. In particular, a number of objections may be raised to the introduction of an allocated quota system. An equitable method of allocating quotas may appear difficult to achieve. Fishermen may feel that quotas will overly restrict their

7/ A variety of terms have been introduced by different authors to describe allocated catch quotas, including: fishermen's quotas, vessel quotas, quantitative rights, and stock certificates (of course, these terms may have slight variations in meaning).

8/ In theory, a certain level of inefficiency may be retained by an allocated quota system, since fishermen may wish to catch their annual quotas early, while abundance remains high. As shown in Clark (1979), however, this is generally a secondary effect, which could (if severe) be countered by reducing the time period of validity of quota units.

freedom of operation, and destroy the opportunity of profiting from a "lucky catch". A quota system may also appear unfamiliar, overly complex and difficult to administer.

All of these objections appear to have some degree of validity, and there are doubtlessly some fisheries for which allocated fishermen's or vessel quotas would be unsuitable. For example, in cases where annual recruitment is both highly variable and unpredictable, there would be no basis upon which to fix annual quota levels. 9/ In most fisheries, however, total quotas can be at least approximately determined prior to the fishing season, with allowance for minor subsequent adjustments if necessary. The total quota can then be allocated to individual fishermen or vessels; annual variations can be handled by adjusting the size of the basic "quota unit" as required, or by changing the total number of quota units.

The problem of fishermen's "luck" must also be given serious consideration. As noted previously, many fishermen seem to expect and to rely upon the occasional lucky catch. A strict quota system might interfere with this situation. However, if quotas were transferable (in any portion) between fishermen, the lucky fisherman could purchase quota units from other fishermen. Such transactions might occur on a one-to-one basis between individual fishermen, but more likely some more or less formal market for (temporary) quota transfers would become established. Such a market would have several beneficial results. Annual fluctuations in fishermen's incomes due to lucky and unlucky catches would be smoothed out. Also, efficiency would be encouraged, since the better fishermen would be in a position to buy quotas from less efficient fishermen, to the mutual benefit of both. 10/

Specifically, an allocated quota system would probably work as follows. Certain fishermen (or vessel owners) would be licensed, and would then automatically receive a certain number of quota certificates at the beginning of each year, each certificate allowing the capture and sale of a certain quantity of fish of given species. These quota certificates could be sold or traded among fishermen without restriction. Of course, each fisherman could also sell his entire quota licence - which would amount simply to a permanent, rather than a temporary transfer of quota rights.

It should be obvious that allocated quotas are the closest realistic approximation to what might be termed "property rights" to portions of a fish population. Like other rights, quota certificates (and licences) would acquire a monetary value reflecting the demand for them, which would in turn reflect fish prices and the costs of fishing. A system of transferable quota licences and certificates would encourage efficiency in the fishery, and would also resolve the problem of permitting new entrants - although entry would of course be open only to those who could afford to buy up an existing quota licence.

It is worth emphasizing once again that an allocated quota system can be expected to perform very differently from a licensing system in terms of encouraging economic efficiency and eliminating wasteful overcapacity. In short, quota allocations encourage efficiency whereas limited entry does the opposite. Both systems encourage innovation, but with very different implications. Under limited entry, innovations are essentially aimed at getting around the regulations, and would be disliked and discouraged by the manager. For quota allocations (especially if transferable), innovations improve efficiency, and would be welcomed by the manager.

The main problems associated with the establishment of an allocated quota system will be (a) determining the initial allocation of quotas, and (b) ensuring smooth operation of the system and preventing evasion. In practice these problems may be rather difficult, but

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9/ A possible method for dealing with this form of variability would be to permit fishermen to average their quotas over several seasons.

10/ There is the danger, of course, that the quotas would eventually come to be owned by an unacceptably small group of fishermen or companies, but in most cases this could be easily prevented by appropriate regulations.

probably no more so than for alternative management systems. Of course the basic biological aspects of management remain the same, except for the possibility that more accurate catch data might be available under the allocated quota system. On the other hand, false reporting of catches might be more prevalent with allocated quotas than with non-exclusive methods of management, in which case catch data could become less reliable. Accurate reporting of catches is in any event a sine qua non of any successful management system.

For practical purposes, an allocated quota system must be sufficiently flexible to permit changes in the total quota from year to year, in response to fluctuations in recruitment. In cases where recruitment can be accurately assessed prior to the fishing season, this can be achieved simply by adjusting the number of quota certificates issued to licence holders each year. In cases where recruitment, and hence total quotas, can only be determined after the start of the fishing season, allocated quotas will either require adjustment during the season, or averaging over successive seasons. Various methods could be used, such as, for example, a 3-level (or n-level) quota system. Three (or n) types of quota certificates would be issued at the beginning of the season - say red, green, and blue certificates. Red certificates would be valid under any circumstances; green certificates would become validated if recruitment levels warranted additional catches, and so on. Such a system could also form the basis of a "catch insurance" programme for fishermen: in poor years (red certificates only), fishermen could receive a subsidy from the insurance fund, whereas in good years (red, green, and blue certificates) fishermen would contribute to the fund. However, alternative methods of dealing with fluctuations could be devised, such as the repurchase of excess quotas by the managing authority (Pearse, 1979).

In case where recruitment cannot be accurately assessed at all, some form of catch quota averaging might prove useful. Alternatively, quotas on fishing effort, rather than on catch, could be used. Effort quotas, however, suffer from difficulties similar to those of vessel licences: fishermen will be motivated to increase effort levels, and management may be hard pressed to control such increases.

Allocated quotas would also be appropriate for the management of multispecies fisheries. Licenced fishermen would receive quota certificates for the various species, or species groups. Because of the uncertainty of the mix of species caught by individual vessels, transferability of quota certificates would be especially important in multispecies fisheries. The problem of by-catches would persist, but should be considerably alleviated by the allocated quota system. In critical situations, however, other types of regulation might have to be superimposed upon the quota system.11/

While the above discussion refers to quota allocations to individual fishermen or vessels, the method can also be used effectively in international fisheries. The general principle remains the same: allocated quotas encourage economic efficiency by removing the competitive incentive that leads to overexpansion of capacity. Of course each nation holding a quota is then faced with its own management problem, which is of the same nature as for a national fishery. The management problems of international fisheries should not be underrated, however. Unless participating states operate in an atmosphere of mutual trust and cooperation, successful joint management becomes virtually impossible. The difficulties that Canada and the United States are currently experiencing in reaching agreement on the management of transboundary stocks, for example, is an indication of the problems that other nations may expect to face.

Especially severe difficulties pertain to the management of highly migratory species, which may migrate through the economic zones of many coastal states, as well as through international waters. An allocated quota system may provide the best approach to the management of these species, but various additional problems will need to be resolved.

11/ The use of allocated quotas in multispecies fisheries is another topic requiring further theoretical analysis.

Perhaps the most important consideration will be flexibility: the quota system should not be unnecessarily complex nor overly restrictive. In particular, it would be advisable for quotas to be transferable without restriction so as to allow coastal states to benefit from their allocations without the necessity of developing their own fishing industry. Transferability of quotas is generally desirable on economic grounds, since it admits flexibility and stimulates efficiency in the fishery.

Taxes

Next we turn to the question of taxes as instruments for fishery management. According to standard economic theory, taxes imposed on fishermen's catches (or on fishing effort) can be used to correct for the "externality" of the common-property fishery. 12/ Economic theorists have tended to favour the use of taxes for such purposes because, in contrast to certain other regulatory instruments, a properly devised tax system avoids economic distortion and encourages efficiency. Thus, as noted above, the use of total (non-allocated) catch quotas in fishery management leads to a worsening of the overcapacity problem, and may also introduce other forms of economic distortion. Similarly, licensing programmes may result in the unwarranted expansion of inputs such as vessel size, horsepower, and so on.

The theoretical attractiveness of taxes is unfortunately offset by rather severe practical difficulties. Indeed, there appears to be no single instance where taxes have actually been used as the principal instrument of fishery management. In order to operate successfully, taxes must be sufficiently high to withdraw all of the economic rent from fishing. 13/ Taxes of the necessary magnitude are obviously likely to be strongly resisted by fishermen. If the fishery already suffers from impoverishment, taxes will obviously make the fishermen worse off, and will in principle drive some fishermen out of the fishery entirely. Indeed, this is precisely how taxes are assumed to operate in reducing total fishing effort. When taxes are used as the exclusive management instrument, fishing rights remain invested in the taxing authority, which is thus able to appropriate all of the economic rent from the resource stock.

This is not to say that the use of taxes is always necessarily inappropriate. For coastal states managing fisheries exploited by foreign vessels operating within their 200-mile zones, substantial charges for fishing privileges will control the demand, and at the same time generate substantial revenues. Indeed, the failure to impose such charges essentially constitutes foreign aid.

For domestic fisheries, it is a problem of social distribution whether private individuals (fishermen and/or processors) receive the economic benefits from the fishery resource, or whether these benefits are claimed by the state. 14/ If taxes are used, then the entire benefits accrue to the state; if allocated quotas are used, or if licensing is used, benefits accrue to quota or licence holders (subject to the proviso that licensing without allocated quotas may be of limited effectiveness in generating long-term benefits).

An interesting theoretical consideration is the fact that taxes on catch and transferable allocated catch quotas are theoretically equivalent in terms of economic efficiency, at least under the condition that a perfect market is established for the transfer of quotas. Whereas the tax instrument assigns economic rents to the state, allocated catch quotas allow these rents to be captured by the fishing industry - provided, that is, that

12/ See Anderson, 1977, pp.160-178, and Clark, 1979

13/ See Clark, 1979

14/ One situation in which taxation might be feasible (and desirable) arises when purchasing/processing rights are granted to a specific number of firms, which can then be taxed appropriately. See Clark and Munro, 1979

quotas are granted free of charge. Going a step further, we see that by combining allocated quotas with taxes, the management authority can achieve any desired level of sharing of economic benefits between the fishing industry and the state. The simplest way to achieve the desired result would probably be to impose a quota fee.

The theoretical equivalence of taxes and allocated quotas, mentioned above, holds under the assumption of certainty and perfect information with regard to both the biology of the fish stock and the economics of the fishing industry. In practice, the high degree of uncertainty associated with actual fisheries would seem to favour the use of allocated quotas rather than taxes. 15/ The results of a quota system, for example, would be much more predictable than those of a tax system. Also, necessary adjustments in total quotas from year to year (or even within individual years) would be fairly straightforward, whereas adjustments in tax levels might be quite difficult to achieve, and probably impossible on a short-term basis. (In the United States, for example, changes in tax levels would require Congressional approval). By combining a fixed tax level (quota fee) with a system of adjustable allocated catch quotas, flexibility could be achieved without necessarily allocating all economic rent to fishermen.

To summarize, of the three methods of securing rights to fishery resources, allocated catch quotas appear to offer the best alternative, in terms of feasibility and efficiency. A licensing programme, which may be considered as a necessary prerequisite to the allocation of quotas, does not by itself lead to efficient exploitation of the fishery. Taxation will generally not be feasible as the sole means of regulating a domestic fishery, but could well be used in conjunction with an allocated quota system for the purpose of sharing benefits between fishermen and the state.

The possibility of regulating inputs ("fishing effort") rather than output (catch) should also be mentioned. Instead of catch quotas, vessels could possess effort quotas, permitting for example a certain number of days fishing per season. Similarly, effort taxes or fees could be employed. It should be clear, however, that the regulation of fishing effort provides a much less precise or predictable form of quantitative control than does the regulation of catches. An effort quota merely gives the vessel owner the right to spend a certain amount of effort attempting to catch fish, but guarantees no specific catch. If catches are uncertain, fishermen will be strongly motivated to oppose any system based on effort taxes or quotas. Furthermore, the amount of effort employed by a given vessel may be difficult for the authorities to determine, or to control with any accuracy. Finally, inasmuch as accurate catch data (as well as effort data) is required for the scientific management of a fish population, the regulation of catches should be quite feasible in any well managed fishery.

In spite of these limitations, regulation of fishing effort may be the most cost-effective form of management in some circumstances. For example, coastal states with minor domestic fisheries but substantial fishing by foreign vessels may not possess the scientific expertise for a highly sophisticated management programme. In such cases a realistic solution may be to charge foreign vessels a fixed fee (possibly related to vessel size) for each month of fishing, for example.

The purchasing-processing sector

The foregoing discussion pertains to the problem of preventing wasteful overcapacity in the fish catching industry. Overexpansion of processing facilities is also a danger in some fisheries, and may in fact be a consequence of the overexpansion of fishing fleets, which results in a large supply of raw fish for a short period in the year, necessitating a large processing capacity. This latter problem will often be largely eliminated if an allocated vessel quota system is introduced at the outset, since such a system will

15/ This subject also deserves further study.

automatically result in an evening out of the catch over the entire fishing season.

In some existing fisheries the purchasing-processing sector is dominated by a few large firms. These firms may have considerable power over the operation of the fishery generally, particularly if entry of further firms is not allowed. The extreme case arises when the purchasing sector consists of a single firm (monopsony). Even if the monopsonist does not itself own and operate fishing vessels, it possesses virtual sole-ownership rights over the use of the fishery, and can exercise these rights (to maximize profits) via its purchasing and pricing policies. By keeping the price paid to fishermen below the actual value of fish to the firm, the monopsonist discourages excess fishing capacity and overfishing. In effect, the monopsonist is imposing a tax on the fishermen's catch, and is thus collecting the economic rent from the fishery. 16/

Where fishermen are organized into unions or cooperatives, the power of purchasing firms may be abated. In this regard, a vessel licensing programme will clearly strengthen the power of fishermen's organizations - a portion of the rights to the fishery now being vested in the licensed fishermen. To the extent that purchasing firms recognize this fact, it can be expected that they would oppose the establishment of limited-entry schemes. In practice, however, the degree of control held by the purchasing sector is often quite limited. Rationalization of the fishery by means of a vessel quota allocation programme would in most cases be beneficial both to fishermen and to fish purchasers and processors.

Costs of administration

In order for fishery regulation to be effective, the corresponding rights and restrictions must be enforced. In the case of a small local fishery, the fishermen themselves may be able to ensure that the rules are obyed. But in most cases, the authority of the state will be required, and a system of monitoring the fishery and enforcing regulations will become necessary.

The complexity of enforcement procedures will depend on the circumstances. In cases where the entire catch is delivered to a few processing plants, quotas can easily be monitored, and royalties collected. But where catches are delivered to a large number of local markets, quotas or royalties may not be feasible. In such cases the more traditional approaches to management (e.g., closed seasons, gear restrictions, vessel licences) may be appropriate, depending on the size and economic importance of the fishery in question. But it should be recognized that these methods, which do not involve exclusive rights, will normally fail to improve the economic performance of the fishery.

In principle, the government could establish a purchasing (and marketing) authority with sole rights to purchase fish from fishermen. This authority could in turn grant fishing rights (quotas, licences) to individual fishermen. Establishing and operating such an authority, however, would be expensive, and would only be justified for a large, economically important fishery.

International fisheries

The above analysis of the three main methods of securing fishing rights pertains primarily to the management of a national fishery, or the national quota allocations from an international fishery. The next question that arises concerns the methods of allocating national quotas in an international fishery. It seems clear that quota allocations are in fact the only feasible approach to securing rights in international fisheries, since no international authority is likely to be given the rights to collect taxes, or even to restrict access to specific fishermen or vessel owners.

16/ The possibility exists that the monopsonist may wish to purchase less fish than the social optimum, since the price he pays for fish represents the marginal rather than the average cost of effort. For this and other complications, see Clark and Munro, 1979.

In the case of transboundary stocks, national quota allocations can be established by normal negotiation procedures between neighbouring states. The most likely outcome of such negotiations will be some proportional division of the total allowable catch between participating nations. This division of the catch may be fixed on a permanent basis, or may be subject to future revision. The total allowable catch will be determined on the basis of scientific investigation of the stock. However, it is possible that the participating states could disagree over the management policy for various reasons. For example, in the case of a depleted stock, one state might prefer a moratorium, ensuring rapid rehabilitation of the stock, while another state might desire to continue fishing on the depleted stock. But any such differences can also be resolved by negotiation; presumably some compromise policy will emerge. 17/

With regard to national quota allocations, it is worth noting that an international commission is not likely to be given the authority to set allocations itself, since this would imply possession of rights to the resource on the part of the authority. Thus quota allocations can be expected to be made by direct agreement between representatives of the states involved.

The case of high-seas fisheries offers special difficulties, since there is no "formula" for determining quota allocations, or even which countries should receive allocations. If all nations that wish to exploit the resource can agree to cooperate in the formulation and operation of an international commission, then at least the framework for rational management exists. Unfortunately, the existence of a single nation operating outside the commission, or failing to adhere to quotas set by the commission, tends to destroy the motivation of other members to control the level of their catches. Any realistic appraisal of the problems of managing high-seas fisheries must recognize the very serious difficulties associated with the lack of any form of exclusive rights to these resources. It remains to be seen whether exclusive rights to such fisheries will ultimately become established, and if not, whether these resources can be successfully managed in the absence of such rights.

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17/ See Munro, 1979

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APPENDIX 4

GLOSSARY OF TERMS AND CONCEPTS USED IN FISHERY MANAGEMENT

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LIST OF TERMS

Associated Species and Dependent Species
Best Available Scientific Information
Allocation
Catch and Associated Terms
Common Property, Open Access
Conservation
Depleted Species
Economic Efficiency
Ecosystem Management
Exclusive Economic Zone
Fishermen or Vessel Quota
Fishing
Fishing Effort, Fishing Mortality
Highly Migratory Species
Incidental Catch, By-Catch
Limited Entry
Management
Maximum Economic Yield
Maximum Sustainable Yield
Models
Optimum Yield, Optimum Sustainable Yield, Optimum Utilization
Overcapacity
Overfishing
Prices: Market Prices and Shadow Prices
Recruitment
Shared or Transboundary Stocks
Species, Population, Stock, Unit Stock
Surplus
Sustainable Yield

Selected References

Associated Species and Dependent Species

The ICNT (1979), requires (Art. 61) that the coastal state take the effects on "associated or dependent species" into account when establishing management measures for exploited species. Associated species and dependent species are sometimes referred to as interdependent stocks or interdependent species. These terms have as yet no common usage and are vague in nature. Species that might fit into these rather broad categories include those species that have any of the following biological relationships with the exploited species:

(a) prey upon the exploited species,
(b) are preyed upon by it, or
(c) compete with it for food, living space etc.

These interactions can occur at any stage of the life cycle of one or other species. The range of species associated with, or dependent on, a given species can therefore be very large.

Best Available Scientific Information

The ICNT (1979) asserts that fishery decision-making should be based upon the "best scientific evidence available" (Art. 61(2)).

There is no unique definition of best available scientific information, nor does it seem possible to establish a single set of detailed criteria with which to evaluate information. Rather, it is the potential for discretionary use, or misuse, of scientific information by those responsible for the management of living marine resources that may generate problems and, in some instances, conflict, (for example, a coastal state and a country or countries wishing to fish in that coastal state's EEZ may not agree on the information used to determine the amount of foreign fishing to be allowed).

Nonetheless, scientific information can be evaluated in a general way. It has been suggested that two measures of this are: 1) is the science "good" enough, i.e., has the proper data been collected and analyzed according to scientifically acceptable standards; and 2) do all interested scientists or parties have the opportunity to review the data and comments upon them? Also it is necessary to note the distinction between the data that is available and the use made of the data. In essence, one must consider whether better and/or more appropriate data could have been collected and whether the analysis of the data to provide information meets scientific standards.

The use of the term "evidence" in the ICNT, (Art. 61), implies that scientific data will be used to determine specific levels of allowable catch and/or harvesting capacity. It seems that a more appropriate role for scientists would be to present management entities with a set of alternatives with the biological consequences of each.

Allocation

Allocation is the process of apportioning finite resources among specific uses or activities. In the context of fishery management allocation usually refers to the division of the total catch between participants in the fishery. Allocations may be made by weight or number of fish over particular time periods. Allocations may be made to parts of the fishing industry or fishing community. Several allocation systems exist: international allocation systems that grant national allocations in international fisheries and national systems that apportion the resource among individuals or groups of individuals in that country's EEZ.

Allocation of "surplus" available to foreign fishing, in the context of the Third United Nations Conference on the Law of the Sea (UNCLOS III), is within the coastal state's prescriptive jurisdiction. The UNCLOS Informal Composite Negotiating Text (ICNT), provides criteria for such allocation: 1) rights of landlocked and geographically disadvantaged states; 2) paramount interests of the developing countries in the region; 3) rights of traditional fishing interests; and 4) the extent of a state's cooperation in scientific research efforts (ICNT, 1979). In addition the notion of reciprocity is given considerable weight in many coastal states.

Allocation in the domestic national context, usually represents apportioning the allowable catch among user groups or individual fishermen and may be equivalent in some instances to establishing a quota system. Such an allocative system may have the potential to eliminate wasteful effort and excess capacity and may extend the harvesting season, all factors which can contribute to increased economic benefits. It should be noted that these benefits are likely to be realized when the ultimate allocation is at the individual (or very small group) level. Furthermore, the allocative system does not necessarily provide any constraints on the use the fisherman makes of his allocation, and he may therefore pursue a pattern of fishing that is wasteful in terms of the national fishing operation but which makes sense in the context of the individual's objectives.

Catch and Associated Terms

Catch is the weight (as is the case in most fisheries) or number (as is the case in the harvest of whales and seals) of animals removed from a population by fishing. The principle problem associated with the term catch is the variety of terms used in catch and catch/effort statistics and the lack of adequate understanding of, and adherence to the precise meanings of such terms by national statistical publications (FAO, 1974). The following are related terms.

Nominal Catch: the live weight equivalent of the landings; some national statistics use the following to refer to nominal catch:

(a) landings on a round, fresh basis;
(b) landings on a round, whole basis; and
(c) landings on an ex-water weight basis, (FAO, 1974).

Note: nominal catch may differ from landings, this is significant because landings are usually more directly related to fishing mortality (F).

Landings: the weight of fish products brought ashore, i.e. the actual weight of the quantities landed, (FAO, 1974).

Production: this term is thought to be more appropriate for seaweeds, quano, seabird eggs, pearls, shells, corals, sponges, etc. and refers to the primary production data of the above resources, (FAO, 1974).

Gross Catch: the total live weight of fish caught, consisting of:

(a) Retained Catch: the total live weight of fish retained on board to be landed eventually as whole fish or in various processed forms, utilization, losses or gains prior to landing resulting from a variety of events, e.g. consumption by the crew, use for bait, etc., may result in differences between retained catch and nominal catch, (Klawe, 1978).

(b) Discarded Catch: the total live weight of whole fish returned to the sea at the time of capture, (Klawe, 1978).

Gross Removal: the total live weight of fish caught or killed during fishing operations (Klawe, 1978).

Pre-Catch Loss: the total live weight of fish which die as a result of fishing operations but which are not caught, (Klawe, 1978).

Common Property, Open Access

Common property resources refer to resources held or used by all who choose to do so. The term is often used synonymously with "open access resources". A resource is common property when it is not or cannot be owned or used by an individual or individual-like entity to the exclusion of others. Christy and Scott (1965) indicate that one of the reasons a resource remains a common property resource is that the costs of establishing and maintaining exclusive rights are higher than the benefits of such rights (this was especially true as long as resources were perceived as limitless). In fisheries, these costs may be high because the resource extends over relatively large areas and is often highly mobile or irregularly dispersed. It was generally held prior to the extensions of jurisdiction by most states that most, if not all, fishery resources are common property resources to some degree (the following table illustrates a variety of forms of property rights providing users with varying degrees of exclusivity). A characteristic of common property resources of relevance to fishery management is that fishing effort tends to increase until the total revenues derivable from the fishery equal the total costs, i.e. until the economic rent is completely dissipated. The advent of extended zones of coastal state jurisdiction has provided states with an opportunity to alleviate this problem.

Common Property

	right to access	right to exclude others	right to a specified quantity	right to specific resources	exclusion possession
No property	Yes	No	No	No	No
Common Property					
unrestricted access	Yes	No	No	No	No
restricted access	Yes	Yes	No	No	No
quantitatively specified	Yes	Yes	Yes	Yes	No
Sole property					
incorporeal	Yes	Yes	Yes	Yes	No
corporeal	Yes	Yes	Yes	Yes	Yes

(Pearse, P.H., 1979)

Conservation

Conservation has been legally defined as the process of reaching a defined state of the resource (United Nations, 1958). An expansion of the definition has been proposed by Holt and Talbot (1978); conservation is seen as a component of management which, taking current and future values of the resources into consideration, regulates use to maintain the resource system in "desirable states". It is then necessary to identify what the specific "desirable states" are. In so doing, the "basic characteristics of the ecosystem" and the properties of selected species and resource stocks must be taken into account.

The Oxford English Dictionary defines conservation as " .... the action of conserving; preservation from destructive influences, natural decay or waste; .... to keep in safety" (O.E.D., 1979). Clearly, this definition stresses the protective nature of conservation; it is less concerned with utilization of the resource than with its care.

Conservation is often confused with preservation in its strictest sense, i.e. that of maintaining a pristine environment or non-utilization of a resource. Rather it is preservation in the sense of preserving for future yields.

Depleted Species (or stock)

A depleted species of fish has been defined as a species or stock that exhibits "recruitment overfishing", i.e. the spawning stock has been reduced to a level at which the average recruitment is significantly reduced (ACMRR, 1979). It is, however, not always clear whether the decline in average recruit is related to overfishing or to natural causes. It is also necessary to distinguish between depletion of a stock and mere reductions in the abundance of the stock which are inevitable in any exploitation.

Economic Efficiency

Economic efficiency requires minimizing costs for each level of output. Full efficiency occurs when resources are allocated in such a way that the value of the goods and services produced from a given input is maximized. That is, it is not possible to shift an input of any good or service out of production in order to produce more of another good or service without the transaction resulting in a net decrease in the total value of goods and services produced.

There are varying degrees of economic efficiency. Pareto efficiency, a frequently used term in economics, is achieved when no one can be made better off without making someone worse off. While this level of efficiency might be considered the "optimal" level of economic efficiency, it is restrictive as it assumes that no one should be made worse off. A somewhat less optimal level of efficieny is any option that makes some better off and some worse off, but the losers can be compensated. Another level, which may be efficient but not necessarily optimal, occurs when some are better off, some are made worse off but they do not receive compensation, yet the cost of the option is less than the benefits.

The major problem with the term economic efficiency is the misconception that achieving an economically efficient fishery will fulfil the objectives sought by those involved in the fishery since economic criteria are not the only ones considered in the management process. It should also be remembered that meeting the conditions for efficiency does not give the decision-maker any help in choosing between management alternatives that are efficient nor does it help determine whether efficient alternatives are preferable to less efficient alternatives.

Ecosystem Management

Ecosystem management has not so far been operationally defined. The concept of the ecosystem refers to the complex of living organisms and their non-living (abiotic) environment that are inseparably interrelated and interact upon each other. Odum (1971) has defined an ecosystem as " .... any unit that includes all of the organisms in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles (i.e. exchange of materials between living and non-living parts) within the system ...."

From a functional standpoint an ecosystem may be analyzed in terms of energy flow, foodchains, nutrient cycles, diversity, evolution, etc. (Odum, 1971). With respect ot fishery management, an ecosystem approach would imply that the choice of specific management measures would take the results of such analyses into account. At the very least the

effects on the total biomass of each trophic level, of exploitation of one or other species would be studied. The practicalities of such an approach are questionable.

If any ecosystem approach to management was instituted for fisheries, decisions would have to be made taking into account the interactions between the important biotic constituents of the ecosystem. Yet these relationships are not all equally important or equally sensitive and many of them are indirect. Ecosystems are not sufficiently understood at this time to allow the relationships to be readily separated out or the necessary analyses to be made.

Exclusive Economic Zones

The ICNT (1979) describes the exclusive economic zone as ".... an area beyond and adjacent to the territorial sea ...." not to exceed ".... 200 nautical miles from the baselines from which the breadth of the territorial sea is measured." The EEZ is basically an area of extended national jurisdiction that grants the coastal state specific rights and authority with respect to different resources and activities in the area. Under the ICNT, the coastal state may claim:

> "(a) sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the seabed and subsoil and the super-adjacent waters, and with regard to other actitivities for the economic exploitation and exploration of the zone ...."

Coastal state authority extends to the living marine resources and to all the activities related to the exploration and exploitation of such resources with its EEZ. This authority is prescriptive and enforceable in nature and is virtually unrestricted in its scope and application. The establishment of an EEZ also confers certain responsibilities on the coastal state with respect to the protection of fishery resources.

The boundaries of national EEZ's will seldom coincide with natural and biological boundaries e.g. between different stocks.

Fishermen or Vessel Quotas

Fishermen or vessel quotas are the rights to harvest specific quantities of fish as given to individual fishermen or vessels. Such quotas are a means of establishing a system of quantitative rights (Moloney and Pearse, 1979) to a particular fishery resource. Under this system, designated fishermen or vessels operating in a fishery would be allotted a portion of the total catch as determined for that fishery. This can be done within a system for restricting the number of fishermen or vessels in a fishery, although this is not seen as a necessary condition. It has been argued that such a quota system, exclusive of a limited entry scheme, would minimize overcapacity.

Fishing

For management purposes, it is useful to continue to make a distinction between "fishing" as the act of catching fish, and a "fishery", the integrated system of accruing the benefits to be derived from a fish resource. Yet fishing can no longer be considered solely in the narrow technical sense of the actual capture of fish. A broader definition has gained considerable standing largely as a result of the current law of the sea discussions.

Under the ICNT (1979), the coastal state has prescriptive jurisdiction[1/] over all activities and operations that pertain to living resources within the exclusive economic zone. The negotiating text does not define what activities consitute fishing, per se; rather it gives the coastal state the exclusive authority to exploit and regulate exploitation of living resources within the EEZ. "Exploitation" as referred to in the text is virtually synonymous with fishing. Yet this "fishing" includes many facets of a "fishery": exploratory fishing, catching, attempting to catch, loading, handling, transporting, possessing, and disposing of fish. The term "fishing" has thus evolved to represent all operations on the sea that assist directly or indirectly in the utilization of living marine resources. In this setting then, a fishery is only slightly broader in scope, including those operations related to fishing that are land-based, i.e. on-shore processing, storage, marketing, etc. Despite the seeming lack of logic in this legal definition, it should be noted by those involved in the fishery. Clearly, the intention was to give the coastal state jurisdiction over more activities within its zone than could have been exercised previously under the practical definitions of "fishing".

Fishing Effort, Fishing Mortality

Fishing effort is a measure of the capacity available or expended to catch fish; nominal fishing effort serves as an indirect measure of fishing mortality (F). Fishing effort data are useful in studying fish stocks (for example, effort data, when used to calculate catch-per-unit-effort is an important element in estimating the abundance of an exploited fish stock), in calculating fish mortality caused by fishing and in economic analysis of the fishery. However, a distinction should be made between the use of fishing effort for biological and economic studies (Gulland, 1969).

Biologically, fishing effort is often defined in terms of the intensity or magnitude and deployment of gear or equipment, or may be expressed simply as a unit of time fished by standard units of gear and vessel. A more precise definition of this usage is the "nominal fishing effort" (f); this is measured in number of days fished, number of hooks set, etc.

Rothschild (1977) points out that there is ".... no necessary fundamental relation between an expression of the magnitude of any of these terms and the magnitude of the number of fish removed from the population." He recommends that a measure of fishing effort be found that has an "invariant effect upon the fish population", i.e. a measure which does not require consideration of the deployment of fishing operations. He proposed the use of the instantaneous rate of fishing mortality, i.e. the product of the amount of fishing effort per-unit-time (the nominal fishing effort) and the catchability coefficient. Use of the instantaneous rate of fishing mortality as a measure of fishing effort may allow control over that effort to more closely reflect stock abundance.

In the economic sense, effort data give a measure of costs in terms of capital (vessels and gear) running expenses (fuel etc.) and labour. Essentially, effort data are used to calculate the total costs and marginal costs of the fishery, whch allows one to determine whether or not the economic objectives of the fishery are achieved. It should be noted that a unit-of-effort in the economic sense is different than a unit-of-effort in the biological sense. The use of a greatly improved piece of equipment may greatly increase the efforts in the biological sense, but make little difference in the economic sense.

1/ Prescriptive jurisdiction, for use in fishery management, is the competence to prescribe and apply policies and regulations governing the exploitation of living marine resources over which a state claims jurisdiction. (McDougal and Burke, 1962).

Highly-Migratory Species

Highly-migratory species are those species listed as "highly-migratory species" in the ICNT (1979). Highly-migratory species were singled out in international law because their "migratory" nature, however defined, exposed them to several coastal-state management regimes or left them largely unmanaged on the high seas or some combination of both. The ICNT seeks to assure such species some protection, in the form of "cooperative" management.

The list found in Annex I of the ICNT is the result of a negotiating process and not based solely on the scientific criteria. Thus there are some species not included in the list that may carry out longer, or more regular migrations than some of those species included on the list. Some criteria are necessary if the definition is to be at all functional. For example migration (in the sense of ordered and usually seasonal movements) can be distinguished from a random dispersion of a stock or species. Also some distinction should be made between "highly migratory" in the sense of long-distance but not necessarily regular movements versus well-defined, regular movements of a species, possibly over quite short distances. Some consideration might also be given to the proportion of the species that engages in significant migration or dispersion.

Incidental Catch, By-Catch

The incidental catch is that fish stock or species taken in a fishery which is not the target species of the fishery. In essence, it is caught incidental to the target species. Incidental catch is often used synonymously with the term by-catch. These terms can be misleading as incidentally caught species may be of value in themselves, and can contribute significantly to a fishery, biologically, and economically.

The definition is made more problematic because of the difficulties involved in defining "target species" operationally. There are several categories of incidentally caught fish. They include:

1) non-target species of little or no value (for example, the small and mixed species of fish, "trash fish", taken in the shrimp fishery), usually not retained, or retained for industrial utilization;

2) non-target species of no market value but that have value to the operation of the fishery (porpoise in the yellowfin tuna fishery), usually not retained:

3) non-target species of value that cannot be retained because of regulatory measures (halibut or salmon taken by trawlers);

4) non-target or target species of existing or potential market value that are too infrequent or do not comprise sufficient portion of the catch to make separation worthwhile (tropical reef fish used in fish meal), such species may or may not be retained;

5) target species that cannot be retained because of regulatory measures (size or sex limitations);

6) non-target species of value, but not sufficiently abundant to be the principal target.

Limited Entry

In a rough sense, limited entry is any fishery management scheme that attempts to control the amount of inputs that are used to harvest the fish stock, i.e. access to the fishery is no longer completely unrestricted.

There are three basic kinds of limited entry schemes (Anderson, 1977). The first involves effort limitation schemes which include licensing programmes and effort share programmes. Licensing programmes limit the number of licences that are distributed for a particular fishery and only those vessels with licences may fish. Effort share programmes allocate a share or portion of the fishery in terms of effort. A second type of limited entry scheme are fishermen or vessel quotas, these are defined elsewhere in the Glossary. It has also been suggested that certain taxes may be forms of limited entry, notably taxes on effort and taxes on quantity harvested. These appear to be somewhat indirect in their approach, allowing economic factors to constrain entry into a fishery. The tax on effort is designed to capture the opportunity cost of congestion and is essentially an entry charge. The tax on units of the resource extracted reflects the scarcity value of the resource stock (Brown, 1974).

Management

Management is the process of making decisions relating inputs (resources available). to outputs (desired objectives). Any management process involves setting policy, collecting information, making decisions, and evaluating performance. During the initial phase of this process explicit objectives must be established, priorities set, the scope of the management system and management authority determined, and communication between all interested parties established.

Historically fishery management has focused primarily on the biological aspects of the fisheries, concerned primarily with the protection and conservation of fish stocks. It is now clear that if fisheries are to make their fullest contribution to society, social, economic, political and environmental factors must be incorporated into the management process. Greater consideration of the people involved in or affected by the fishery - from boat-builders and fishermen to fish merchants and consumers - is necessary. Fishery management is necessarily concerned with the application of restrictive (regulatory) measures, but it is not concerned only with these. Its scope is wider, and includes a strong role in planning and executing fishery development.

Maximum Economic Yield

A general definition of maximum economic yield (MEY) is that it is the value of the greatest difference between the costs of inputs and the value of the outputs (catch). It occurs at that level of output where the marginal value of the catch is equal to the marginal cost of harvesting the fish. If the price of the fish varies with the output landed, MEY will occur at the point where the sum of profit to the industry and consumer surplus is maximized (Anderson, 1979). It should be noted that it is the marginal cost and marginal revenue to the fisherman, and not necessarily to society, that is generally used in defining MEY. The maximum economic yield is usually attained at a physical level less than the maximum sustainable physical level, and will be taken with less fishing.

Maximum Sustainable Yield

Maximum sustainable yield is the greatest yield that can be removed each year without impairing the capacity of the resource to renew itself. Because of natural variations in stock abundance, MSY is often considered to be the maximum yield available for harvesting under average natural conditions. MSY has been used as a reference point for management purposes to describe the maximum potential productivity of a stock in terms of catch and is usually associated with an exploitation rate, F_{msy}, that is required to hold the stock at that level of productivity (ACMRR, 1979). It may, in some instances, be useful to make a distinction between MSY and MSY per recruit and the respective exploitation rates, F_{msy} and F_{max}. F_{msy} is that fishing mortality rate at which the average long-term catch from a fish stock as a whole is greatest, while F_{max} is that fishing mortality rate at which the average catch per recruit is at a maximum. In absence of detailed knowledge of the

recruitment-spawning stock size relationship (or any knowledge of underlying factors influencing annual recruitment levels), F_{msy} and F_{max} estimates cannot be distinguished from one another.

A major problem of MSY has been the almost blind acceptance of estimates of MSY. All too frequently, fishery managers have relied heavily on estimates of the MSY for a particular stock without taking into account the assumptions made to reach those estimates. Furthermore, MSY is often erroneously viewed as a static point when in fact MSY is as dynamic in nature as the fish populations it seeks to estimate.

The use of MSY as a measure of "maximum potential productivity" expanded until MSY became the objective of fishery management instead of its foundation. The notion prevailed that what was biologically right for the resource was right for the fishery as a whole.

This notion has been eroded considerably (Larkin, 1977). Although the ICNT continues to adhere to MSY as the biological basis for the management of living marine resources, it also provides that MSY be qualified (i.e. in some instances modified) by relevant social, economic, and environmental factors.

Models

A model is a set of equations or other formal descriptions of the relationships in a situation that cannot be directly observed. A model can help visualize complex relationships. The development of a model requires that one follows a method setting out in a structured way, the parameters and dynamics of a system.

Models are ".... mechanisms to explain and simplify a concept or theory and are used as teaching tools. They have been used by management biologists to gauge or reference the status of exploited stocks. Over time many of the identified reference points of the models have been used to establish harvest strategies, conservation principles and economic principles regarding fishery management, frequently ignoring the underlying model assumptions and their limitations" (ACMRR, 1979). Integration of biological, economic, and social fishery strategies into a more comprehensive model has not proven particularly successful as yet.

Optimum Yield, Optimum Sustainable Yield, Optimum Utilization

Optimum sustainable yield (OSY) is that yield, in biological and/or economic terms, or that rate of utilization that will ensure the "best"1/ use of a resource over a period. A distinction may be made between OSY and optimum yield (OY); the latter will not necessarily be sustainable, but may set for one or two years to take account of short-term factors. OSY, and usually also OY are less than or equal to the maximum sustainable yield and will generally be taken with less fishing. There are exceptions, for example, in the case of Greenland fisheries, the need for employment has a high priority, and the amount of fishing to achieve OY may exceed that required for MSY.

OY represents a resolution between competing objectives; the resolution is achieved through optimization. The concept of optimization is crucial to a discussion of optimum yield.

1/ "Optimum" or "optimal" are not as synonyms for best. "Best" is used in this discussion in the economic sense, i.e. the "least worst" result that can be obtained within a given set of constraints. It is not meant to imply that the "best" result is the one that would be chosen in the absence of constraints or conflicting objectives.

Originally an economic concept, optimization has been applied, often uncritically and with little success, in management decisions where an array of different objectives must be reconciled. Optimization is that process that seeks to attain the "optimal" value of a resource. This process assesses the benefits and costs (including the opportunity costs of alternatives foregone) of each objective, properly weighted according to its established priority, to determine the rate of or type of use of a resource that will generate the "best" combination of benefits. Optimization is distinct from maximization in that the prescribed use may not generate the greatest amount of benefits; it does not necessarily seek to obtain the most from a resource (as does a maximization process), rather it seeks to "best" use within a constraint set.

The "optimal" result is by no means an absolute: priorities change and as they do the weight given each objective will change as well, producing a different optimal level. This follows in the determination of optimum yields as well. Optimum utilization is the pattern of exploitation involved in taking OSY or OY.

Overcapacity

Overcapacity results when there is more capital and/or labour operating in a given fishery, or for a specific gear type, than is necessary to capture the allowable catch or to realize the maximum economic benefits from a fishery. Overcapacity of a fishery tends to dissipate the economic rent that could be derived from the fishery if the capacity was reduced. A situation may develop in which no economic rent is being derived from the fishery (this is often referred to as economic overfishing). Overcapacity is often used synonymously with overcapitalization.

A case may be made for allowing a fishery to become "overcapitalized" if one takes into account the "optimal capital budgets" of the fishery (Rothschild, 1971). Yet, until explicit criteria are established for determining the optimum rates of utilization of the resource and the inputs necessary for such utilization, one can only evaluate the capitalization of a fishery by conventional models of economic efficiency with respect to the capital and labour investments necessary to capture the allowable catch with the greatest economic return.

If one wishes to optimize the utilization of a fishery resource overcapitalization may be required to achieve other objectives, such as increased employment. In such instances, overcapitalization must still be counted as a cost, as it may introduce a further amount of economic inefficiency into the system: the catch-per-unit vessel may be reduced below that necessary to cover operating costs; and the excess capacity may have a depressing effect on wage levels.

Overfishing

Simply put, overfishing is ".... fishing harder .... than some desirable level" (ACMRR, 1979). Yet this definition fails to make a useful distinction, that between overfishing in the sense of overexploitation of the resource (biological overfishing) and overcapitalization of the fishery (economic overfishing) (Gulland and Robinson, 1973).

Economic overfishing exists when a fishery is generating no economic rent primarily because an excessive level of effort is employed in the fishery (see Overcapacity). Economic overfishing does not imply biological overfishing, as the latter is not necessarily the result of excess capacity.

Some changes in the average fish size, in the proportion of young fish in the stock, and/or in the growth rate is inevitable in any exploited fishery. Yet biological overfishing may create situations in which the fishing mortality reduces the biomass to a level where recruitment and/or growth are adversely affected. It is useful to distinguish between "growth" and "recruitment" overfishing. Growth overfishing occurs when fishing

mortality (F) is greater than the rate of fishing mortality at which the average catch per recruit is at a maximum (F_{max}). Recruitment overfishing is defined as a situation in which the spawning stock has been reduced to a level at which the average recruitment to the stock is significantly reduced.

Prices: Market Prices and Shadow Prices

Prices are essentially measures of the relative importance of one commodity to another; they reflect an individual's or society's index of perceived need. For purposes of fisheries management, two kinds of prices are important: market prices and shadow prices.

Market prices are those prices at which goods are exchanged in a free market economy. Market prices should reflect societal preferences and values. However, because of market failures, prices may not reflect society's true willingness to pay for those goods and services. This is especially true in many aspects of natural resources; when the market price does not adequately reflect or measure the value of a resource, "shadow prices" are often substituted. Shadow price refers to the value of a resource imputed from its future productivity rather than its direct sale or market value.

Recruitment

Recruitment refers to one aspect of the population dynamics of a fish stock and can be divided into two distinct processes: recruitment to a stock or population and recruitment to the exploitable phase of a stock. In the first instance, recruitment is the general replacement of fish to a stock or population (Cushing, 1977). In the second instance, recruitment is the number of fish in a single year-class (usually called a cohort) that enters the exploitable phase of a stock within a given period. Recruitment may also be thought of in terms of "selection", i.e. that time when fish become liable to contact with fishing gear and are more likely to be taken. This may involve an actual movement (for example, from nursery areas to fishing grounds) or a change in habit (Gulland, 1969). However, recruitment and selection are distinct concepts: fish may be recruited into the exploitable portion of a fish stock, yet may not be caught by a particular gear, due, for example, to their not being retained by the meshes of a trawl net.

Shared or Transboundary Stocks

The concept of shared or transboundary stocks has emerged over the past decade largely as a result of the extension of national jurisdiction and the advent of the exclusive economic zone. The ICNT (1979) defines shared or transboundary stocks as a ".... stock or stocks of associated species ...." which occur either within the EEZ of two or more coastal states or which occur both within the EEZ and in an area beyond and adjacent to the zone. The text obligates states to coordinate conservation and development efforts. However, this is subject to other provisions of the text, one of which gives the coastal state the authority to establish the allowable catch for fishery resources within its EEZ. Unless the coastal states involved closely coordinate their respective management regimes with respect to shared stocks, the overall catch for the resource may exceed the MSY and/or other management objectives for that stock.

The ICNT does not give a clear definition of shared or transboundary stocks; for instance, it does not make a distinction between life history stages and/or stock availability to the fishermen. A proposed definition for a shared stock is ".... any stock which an action of one nation in its EEZ could influence some attribute of the stock in another EEZ" (ACMRR, 1979). This definition, albeit technically correct, is rather too broad to be of practical value at this time. The definition can be everything from fishing activities to modification of the habitat. While countries may be willing to relinquish some of their sovereignty in terms of external control of fishing operations, it is highly unlikely that countries will be willing to modify their actions with respect to a resource's habitat,

i.e. part of a state's sovereign territory. Acceptance of such a broad definition could hinder progress towards joint management of shared stocks. For example, a shared stock might be any of the following: a) a stock which the adult or exploitable portion of the population moves freely between two or more EEZ's; b) a stock where juveniles live in one zone and adults in another or outside the EEZ; and c) anadromous and/or highly migratory species (shared stocks, in a broad sense, could include anadromous or highly migratory species, yet such species possess unique characteristics that distinguish them from other species generally; therefore, it may be more useful to treat these species separately).

Species, Population, Stock, Unit Stock

The terms species, population, stock, and unit stock are used for numerous purposes in fisheries literature, often with little regard to population biology or genetics (ACMRR, 1979). Although one can give a definition of these terms, be they scientific definitions or so-called working definitions, the practical application of each ultimately depends upon the extent to which individuals of the species, population, or stock can be identified. The following are offered more as differentiations than as definitions.

Species - ".... a species is a natural population or group of populations normally isolated by genetic, ecological, pathological and/or mechanical barriers from other populations with which they might breed." (Royce, 1973).

Population - for purposes of research and data collection, populations can be defined in the statistical sense as ".... all the subjects .... of the kind about which one wishes to generalize from a sample." (Holden and Raitt, 1974).

In a management sense, population might be considered all the individuals of a certain species inhabiting a specified region. This can be divided into subpopulations which are self-sustaining genetic units. Subpopulation is often used synonymously with unit stock. (ACMRR, 1979).

Stock - an exploitable group of fish, of which there may be more than one per species, existing in a common spatial arrangement, but with limited genetic exchange with adjacent populations of the same species, at a particular time.

Unit Stock - ".... a group of individuals of the same species whose gains by immigration and whose losses by emigration if any, are negligible in relation to the rates of growth and mortality." (Holden and Raitt, 1974).

The term stock is subject to considerable variation in interpretation and in degrees of discreteness. The differences between stock and unit stock is not always readily apparent or definable. As a consequence, for purposes of fishery management, the terms tend to be used synonymously. It may be reasonable from a pragmatic perspective, to consider a stock or unit stock as a self-contained population unit, where fishing upon one stock or unit stock has no effect upon the individuals of other stocks of the same species. Given the difficulty of defining these terms, it is essential that a specific and complete description of one's use of the terms be included as an integral part of management actions.

Surplus

Surplus has come to have two separate meanings. In the biological sense surplus is that proportion of the maximum sustainable yield that is not taken by the on-going fishery but that could be taken by additional fishing. Some consider this "surplus" to be wasted, a portion of the resource that could provide additional benefits to man if it could be taken at acceptable cost.

With the advent of the exclusive economic zone, surplus has taken on a legal definition. In this context, it is the amount of the allowable catch within a coastal state's EEZ which that state cannot or chooses not to harvest. If the domestic fishery does not have the capacity to harvest the entire allowable catch, foreign fishing countries shall then be granted access to this "surplus". The magnitude of the surplus, if it exists, depends on how the allowable catch is determined. In both instances, it should be recognized that harvesting the surplus may have detrimental effects on the existing fishery. The most likely result will be an increase in the cost per unit fishing effort as existing fishermen may be forced to compete with additional fishing units. Also, the potential for overestimating the sustainable yield always exists; an unharvested "surplus" affords the resource additional safeguards.

Sustainable Yield

Under constant environmental conditions yield can be defined as the level of catch where the population neither increases nor decreases; this level of catch can be maintained on a perpetual basis. Thus sustainable yield is obtained by adhering to some fixed fishing mortality rate.

In practice, with a variable environment, even if the fishing mortality is kept at the level sustained over time, the amount of fish available for exploitation will not always be the same. The stocks may vary in abundance from year to year in response to a variety of changing factors.

A concept related to sustainable yield is that of replacement yield as set out by Gulland and Boerema (1973). Replacement yield, used primarily with respect to whale populations, especially those experiencing changes in abundance, is that catch which, if taken, will leave the abundance of the exploitable part of the population at the same level at the end of the year as at the beginning - for a particular year. This final point is critical as there is no concept of continuity inherent in replacement yield.

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APPENDIX 5

COPING WITH VARIABILITY IN FISHERIES

by

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EXECUTIVE SUMMARY

Year-to-year fluctuations in recruitment and migration of marine fish stocks have substantial economic consequences for the fishing industry. Variations in growth and natural mortality rates are also important to long-term fishery trends, but, typically, have less impact than recruitment variations.

Currently, scientists have limited ability to define causal mechanisms of such phenomena as the determination of year-class size and are not able to predict fish stock sizes five years ahead. Among the factors making prediction difficult are: insufficient accuracy in measuring fish stock abundance, high serial correlations confounding the influence of causal factors, and the complexity of natural processes which can be shown qualitatively to depend on many factors. Fishery managers must be prepared to accept equivocal advice and uncertain forecasts for the foreseeable future.

Variations in the ocean climate, or large-scale statistical properties of the oceans have been shown to influence recruitment and movement of fish stocks. Other factors believed to affect recruitment include predation and rates of exploitation of fish stocks by man.

While fishery managers cannot eliminate or even accurately predict variation in fish stocks, means are available to reduce the unfavourable economic impact of such variability on the fishing industry. These options include catch insurance, control of fishing gear, limitation of fishery mortality rates, and influencing the composition of fishing fleets. Such measures can, in some instances, reduce year-to-year variation by 50 percent or more.

Introduction

At its 1978 Rome meeting, the ACMRR Working Party on the Scientific Basis of Determining Management Measures, attention was focussed on the need to examine the sources of variation in fish stocks relative to fisheries, the means of predicting such variation, and the strategies to deal with it. This paper gives a brief review of major sources of variation in marine fisheries, scientific capabilities to predict, and means of coping with variation in fish stocks.

Other sources of variation of concern to the fishing industry such as fluctuations in the costs of fuel and supplies and price fluctuations are not considered here.

While it is not possible to eliminate natural variation or even to predict accurately the status of fish stocks several years into the future, options are available to fisheries management to reduce the economic impact of such fluctuations on the fishing industry.

Variability of the resource

Net, and hence surplus, production or change in weight of fish stocks depends on the biological parameters of growth, natural mortality, and recruitment. Net production defines biological limits on catches over periods of years. Net growth rates in the exploited phase can be influenced indirectly by the intensity and pattern of fishing mortality; however the remaining factors are not directly so influenced. Of the three parameters, the impact of natural fluctuations is strongest on recruitment.

Hennemuth, Palmer, and Brown (1979) tabulated the coefficients of variation and serial correlations of recruitment in numbers for 18 stocks of several species. Coefficients of variation of year-class size varied from 0.25 for George's Bank cod to 1.43 for North Sea mackerel. Estimated serial correlations for a one-year lag varied from -.224 for North Sea herring to .575 for George's Bank cod. Ratios of estimates for the smallest to the largest observed year-classes for various stocks varied from 2.5:1 to 2700:1. Of the stocks examined, haddock appeared the most variable but other groundfish appeared less variable than pelagic species.

Large coefficients of variation tend to occur in fisheries where single very large year-classes dominate the catch composition for many years such as the East Newfoundland and Atlanto-Scandian herring fisheries. Such year-classes can be pulse fished, as was the case with haddock on George's Bank in the late 1960s, with resulting wide fluctuations in catches.

Fluctuations in growth rates are much less than those of recruitment. Nevertheless, the cumulative effects of changing growth rates frequently results in changes of 25 percent or more in mean weight at age for the same stock over a five to ten year period. This has occurred in the 1970s in some Northwest Atlantic cod stocks.

Variation in natural (not due to fishing) mortality rates is difficult to detect because fish dying from natural causes are rarely observed directly. There have been instances of massive mortalities due to epidemics, e.g., the death of hundreds of thousands of tons of herring in the Gulf of St. Lawrence in 1955 (Sinderman, 1958).

Variation of migrations and local movements of fish stocks is common and greatly affects the success of fixed gear fisheries. The availability of mackerel to Newfoundland inshore fisheries, for example, depends on the extent of the annual northward migration from New England waters and local movements of warm water into Newfoundland bays.

Prediction of variability

Current scientific competence to predict recruitment to fisheries and stock biomasses years in advance is extremely limited. The consequences of alternative management strategies on fish stocks and the fishing industry cannot be foreseen with precision. Reliable prediction depends on knowledge of causal mechanisms and estimates of parameters such as year-class strengths. Three factors in particular contribute to scientific inability to predict the dynamics of marine fish stocks:

1. Measurement: Fish stock biomasses are estimated by such means as acoustic or trawl surveys by research vessels and analysis of commercial catches and fishing effort. The ICNAF Biological Surveys Subcommittee reviewed, in 1978, research vessel trawl surveys in the Northwest Atlantic and found that the resulting indices of relative abundance typically have ± 50 percent margins of error unless more than one-hundred sets are made in the area of stock occurrence. In some instances, stock sizes and biomasses can be estimated historically for commercially important species by such methods as Pope's (1972) cohort analysis, but this is effective only retrospectively and is not useful when a species is lightly exploited. Young fish surveys are sometimes conducted to forecast recruitment to fisheries. These forecasts, while valuable, are also imprecise. It is easy to formulate a plausible hypothesis involving, for example, interspecific competition influencing growth rates, but not so easy to obtain direct and accurate measurements of the relevant quantities.

2. Autocorrelation: Typically, quantities such as stock biomasses vary smoothly from year-to-year due to the contribution of several year-classes and also due to trends in fishing mortality. The attendant autocorrelations can be very high so that trends persist for several years. Unrelated but parallel trends frequently occur, resulting in spurious correlations and the confounding of causal factors. Thus, exceptionally long time series are necessary for observed correlation to be convincing evidence of causality. Unfortunately, information on such items as year-class sizes is obtainable at the rate of one point per year so that the basis for statistical inference is always weak.

3. Complexity: It is common that qualitative evidence can be found for the effect of a number of factors influencing key events like the determination of year-class size. Thus, many alternative hypotheses can be put forward to explain observed events. The explaining power of multiple alternatives typically exceeds the discriminating power of data series.

Knowledge of year-class strength increases with age so that exploitation patterns involving relatively low fishing mortality rates lead to better forecasts, due to the relatively large number of exploited year-classes. Problems of projecting when fishery mortalities are high are discussed in Doubleday (1979).

Due to these and related considerations, very few causal relationships have been conclusively established and key problems like the determination of the mechanism and prediction of recruitment remain unsolved. At the current state of the art, it is necessary to live with uncertain forecasts and inconclusive analyses of the implications of alternative policies.

Sources of variability

Sources of variation are easy to postulate but hard to verify quantitatively. Perhaps the most basic source is changes in the ocean climate or large-scale statistical properties of the ocean. J. Walsh (1978), in an analysis of event scales in the Eastern/Tropical Pacific, found that climatic shifts on a scale of years apparently induce a re-location of marine communities representing large changes in local availability of fish to man. He discussed the well-known warm El Niño current off the Peruvian coast, noting that warm

temperature anomalies had occurred about every 3.5 years during the past 30 years in this area, with major El Niños in 1941, 1957, 1965 and 1972, averaging 10.3 years apart. Declines in the number of guano birds (predators on anchoveta) occurred after these major El Niños, but the anchoveta stocks did not drop severely until 1972 when the warm current was accompanied by heavy fishing pressure. Smith (1978) hypothesized that the 400-fold reduction observed in the northern population of the California sardine was partly due to direct effects of the extensive fishery and partly to environmental causes. The fishery reduced the number of year-classes in the spawning stock from 10 to 2 so that recruitment failures in two successive years dramatically reduced the spawning stock. The summer spawning stock occupied a smaller range than did the unexploited stock, so that locally unfavourable recruitment conditions had more serious consequences. The area of high zooplankton productivity expanded and contracted historically in response to climatic changes. The reduced stock was less likely to cover the spawning grounds with best chances for year-class success (high zooplankton abundance). Indirect evidence of the influence of climate on fish stocks was produced by Garrod and Colebrook (1978) who related plankton and fish population variations to large-scale variations in North Atlantic wind patterns.

Apparently, large-scale climatic events definitely influence growth and recruitment of fish stocks with coastal pelagic fisheries being particularly sensitive to such effects. Some authors consider that high rates of fishing mortality increase the vulnerability of stocks to climatic fluctuations by reducing the size and number of age groups of the spawning stock and reducing the range of the stock.

Biological factors have also been shown to influence average levels of recruitment. The present state of scientific knowledge (Parrish, 1973) indicates weak causal links between indices such as spawning stock biomass and mean recruitment levels. Typically, the residual scatter about such stock and recruit relationships gives them very little predictive value although they can be used for comparative evaluation of alternative long-term management strategies.

Anderson and Ursin (1977) maintain that predation is a significant determination of year-class size in North Sea fish stocks. This consideration has influenced the advice of scientific Working Groups regarding management strategies which would greatly increase predator stock biomass.

The conclusions permitted by present knowledge of large-scale variability in fisheries are few. Long-term and large-scale trends are important, especially in coastal pelagic fisheries. High levels of fishing mortality seem to increase vulnerability of stocks to such events. Basic research is needed to describe the influence of environment on vital rates of larvae and young fish to identify causal mechanisms and to forecast future trends in specific cases. When exploiting coastal pelagic stocks for the first time, it is desirable to obtain historical evidence of past fluctuations of the ocean climate and the stocks through such means as temperature records, past observations of related species, and other indirect means.

Coping with variability

Although fluctuations in recruitment, growth and movement of fish stocks are not currently predictable, management strategies can influence the extent of variation and its effect on fishermen. Management options include:

1. Insurance: Movements of fish stocks are not predictable. Different fishing gears have differing vulnerability to this factor. Large freezer trawlers are able to move great distances to find concentrations of fish. Smaller trawlers are more limited in their effective range and gill-netters still more so. A particularly striking example of vulnerability of a sector of the fishing industry to changing availability is the herring weir fishery in the Bay of Fundy, Canada.

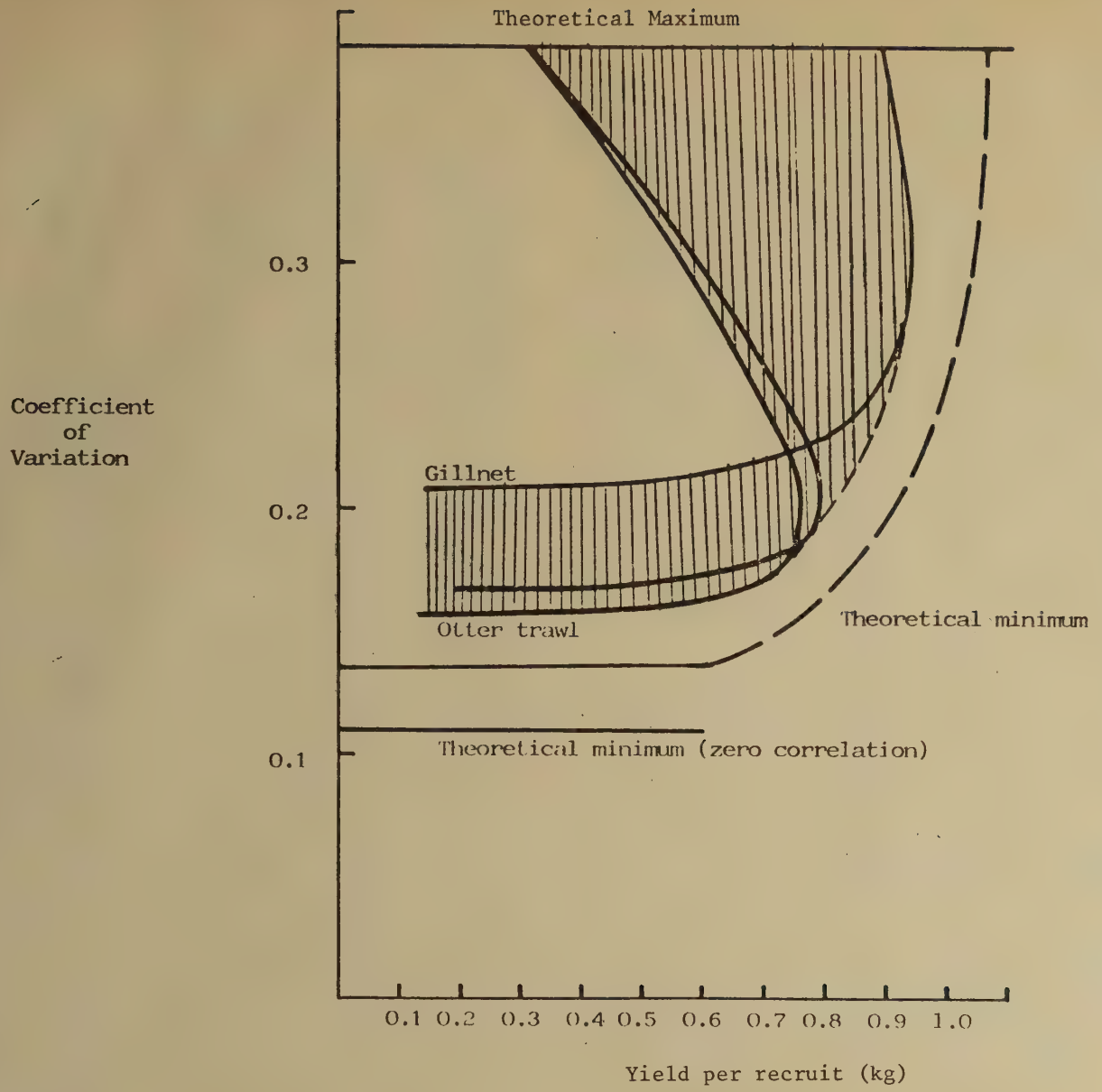

Figure 1. Fluctuations due to recruitment for hypothetical fisheries on Southern Gulf of St. Lawrence cod.

The distribution of income to approximately 250 weirs of this fishery is extremely skewed. In 1977, for example, 70 percent of the weirs had less than the average income, and the median income was 42 percent of the average. The highest income was almost 1 500 times the smallest. Some of this variation was due to the systematic differences between location (a factor of four between districts) and size of weir, but much of it is due to the presence, or absence, of inshore migrations of small herring which form the main catch of these weirs.

In 1979, the Government of Canada initiated a catch insurance scheme. The intent of the scheme is to ensure that all weir fishermen be guaranteed enough income to be able to maintain their weir after a low income year. Extensive consultations with the weir fishermen's association led to the establishment of $5,000.00 as the cost of maintaining a weir. Based on this, a sliding scale of payments was developed, varying linearly from $5,000.00 for a weir with zero income, to $0.00 for a weir earning $10,000.00.

Initially, the plan is financed by a Federal contribution but continued operation is based on contributions of 3 percent of earnings by participating fishermen. The fiscal details may change on review after one year of operation.

2. Distribution of fishing mortality with age: When more than one age-class can be exploited, the mix of gears and the mesh sizes adopted influence the year-to-year variation in catches and catch rates as well as the yield per recruit obtained. This author has developed a mathematical method (to appear elsewhere) for evaluating the effects of alternative gears on multi-age fisheries.

For the sake of concreteness, Fig.1 shows a mixed otter trawl and gill-net fishery for cod in the Southern Gulf of St. Lawrence. The selection patterns are hypothetical, with gradual recruitment from age three to six with full recruitment thereafter for the otter trawl component and gradual recruitment from ages seven to nine for gill-nets, declining gradually for older fish. Observed autocorrelations in year-class sizes for the period 1950 to 1978 were used. For the 1978 mean weights at age, and a natural mortality rate of 0.2 an unexploited year-class reaches a maximum weight of 1.06 kg per recruit at age nine.

Observed autocorrelations cause the minimum coefficient of variation (standard derivation of catch ÷ mean catch = c.v.) to be 20 percent higher than would occur with independence. The theoretical minimum for an ideal pattern of fishing mortality with age increases for yields above 0.6 kg per recruit, rising steeply to the maximum. A pure otter trawl fishery has c.v. about 15 percent greater than the theoretical minimum for yields of up to 0.7 kg per recruit, diverging gradually to a yield of 0.75 kg per recruit (about $F_{0.1}$, the rate of fishing mortality where the marginal rate of increase of yield per recruit is 10 percent of that at F = 0.) and then very sharply upwards. The pure gill-net fishery is initially 50 percent more variable than the minimum and diverges rapidly above a yield of 0.9 kg per recruit. The shaded region shows possible combinations of trawl and gill-net components. Beyond $F_{max.}$, yield decreases and variability increases sharply. The intercept with the upper bound occurs at the yield per recruit achieved when F becomes infinitely large, at the first age caught by one of the gears.

For low levels of fishing mortality, the c.v. is determined by the partial recruitment pattern and is almost independent of the fishing mortality rate. As the fishing mortality exceeds $F_{0.1}$, the fishery concentrates on progressively fewer year-classes so that the c.v. increases steeply.

A diagram like this can be drawn for any stock with annual recruitment. The theoretically admissible region depends on the number of age groups that can be exploited. For Sebastes spp., it is possible to spread the catch over 15 to 25 age classes with the theoretical minimum for uncorrelated recruitment from 1/4 to 1/5 of

the maximum. For short-lived spp. like Illex illecebrocis (annual), the minimum and maximum are equal. The theoretically optimum distribution of yield over ages is uniform for uncorrelated recruitment, but it is uneven if correlations occur.

The c.v. is inversely related to the "available biomass" defined as the partial recruitment factors times the average biomass at age mid-way through the fishery. Thus, high variability is associated with low catch per unit effort.

The calculations leading to Figure 1 ignored the effect of exploitation on mean recruitment and the statistical distribution of recruitment. As discussed under the heading "sources of variability" there is evidence that the variability of recruitment increases with high rates of fishing mortality. Taking this factor into consideration would increase the steepness of rising coefficients of variation beyond $F_{0.1}$ and reinforce the conclusions of this section.

3. Rate of fishing mortality: Several authors have examined the theoretical implications of annual variability on fisheries governed by time stationary models. Lett and co-authors worked with complex, density-dependent age structured models for specific stocks, while other authors have generally introduced variability into general production models in various, hypothetical ways. May et al.(1978) reviewed earlier work and concluded that there was no unambiguous solution to the optimal management of such stochastic systems, but there were important trade-offs between high levels of fluctuation and yields. In their view, attempts to extract maximum yields cause large fluctuations and poor parameter estimation.

While these studies are theoretical and involve unverified assumptions, the general conclusions are in agreement with results obtained by this author using the methods of the previous section to examine multi-age class fisheries. They also are in agreement with the qualitative conclusions of Smith and others that intense fishing is likely to increase fish stock fluctuations.

In most situations, high levels of fishing mortality can be expected to lead to high year-to-year variability of catches. Reduction of fishing mortality rates below F_{max} can be expected to stabilize catches as well as increasing catch rates.

4. Fleet composition: Typically, small to medium vessels (less than 250 GRT) cope with varying availability and abundance of target species, as well as market fluctuations, by directing their effort to a variety of species within a limited area. Groundfish trawlers, for example, can aim for cod, haddock, or redfish in Nova Scotia waters. Some vessels catch lobsters part of the year and groundfish or herring the rest.

Large vessels are able to go where fish are abundant although they are less able to switch species. Thus, they can contribute to greater diversification of the risks of natural variation differently than smaller vessels.

Typically, with equal abundance of fish and equal availability, fixed gear is more cost efficient than mobile gear, and efficiency tends to drop with increased vessel size when measured on the basis of tonnage or horsepower (see e.g., Garrod, 1979). Thus, the diversification of options compensates reduced efficiency. The use of fixed or inshore gear however has a tendency to cause gluts of fish which can depress prices, render processing inefficient, and close doors to prospective markets where continuity of supply is needed. The use of large vessels, which can follow seasonal migrations, allows the peaks of landings to be smoothed out with gains to the secondary industry. It is worth noting that large trawlers are frequently owned by integrated companies with processing plants.

In the context of highly volatile stocks like squid and capelin, a case can be made for a nation to acquire only sufficient capacity to harvest the minimum expected future annual catch and to invite highly mobile, distant water fleets to catch the

highly fluctuating remainder under licence. It is still necessary in this case to develop a short-term forecasting ability of six months to one year to allow distant water fleets to respond to opportunities offered.

Conclusions

Variability in recruitment and movement of fish stocks has substantial economic consequences on the fishing industry. Variability in growth rates and natural mortality rates typically has less economic impact.

The present state of fisheries science does not permit predictions of stock abundance to be made several years in advance. Environmental and biological factors influencing resource variability have been identified, but quantitative models of causal mechanisms are few and remain a subject for debate. Large-scale changes in ocean climate, the abundance of predators and prey, and fishing intensity have all been advocated as factors in the determination of growth rates and year-class size.

Several management measures can be taken to reduce the effects of variation in marine fish resources on the fishing industry. These include catch insurance, control of fishing gear, limitation of fishing mortality rates, and influencing the composition of fishing fleets.

Variability in marine fish resources should be recognized as a factor of economic importance to the fishing industry and should be considered explicitly in fleet development planning.

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APPENDIX 6

DATA AND COMMUNICATION IN AQUATIC RESOURCE MANAGEMENT: THE BASIS FOR DECISION MAKING

by

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This paper explains why fishery data are important and basic to resource management; reviews the technical nature of data and information; compares the state-of-the-art in industry/commerce with that in fisheries; and suggests areas deserving of priority attention in fishery management.

The Value of Information

As Jensen (1978) has noted, the full costs of economic growth often have not been assessed or recognized within the same time frame. The result has been a world of continual corrective action for past transgressions against resources and the environment. Simultaneously our concern extends to the future. The consequence has been to force resource management into a reactive state (usually late) rather than into an anticipatory mode. The result is frequently a response to coping with the symptoms or consequences of the problem rather than the underlying causes. It has been argued that in the case of most aquatic resources sufficient data are not available for effective management, which in turn results in the non- (and occasionally mis-) management of resources. The decision-making process requires information to reduce the uncertainty over the outcome, even if it be a decision to do nothing - albeit by choice. Regardless of management goal, data in some form are required to fill the information need for decision-making.

Timely information is not only a resource but a commodity. As early as 1971 an OECD report stated "Perhaps the most important event of the next decade will be recognition of the value of information - the right information, reliable and relevant to our needs, available in a useful form to all those that need it." In many areas the appropriate information communicated on a timely and acceptable basis is considered as the most valuable commodity of management.

Management might be defined as the function of planning, organizing, coordinating, directing, controlling and supervising to reach a given result. It must be recognized at the outset that in fishery management value to society in the broad sense is the overall goal. Though difficult to quantify this is one meaning of Optimum Sustained Yield (OSY). This means that the short-term policy objectives should be consistent with the long range societal goals whether these be the acquisition of capital, maintenance of a protein base, raising of living standards or some combination of these elements. Usually, conservation as manifested through the long-range maintenance of sufficient reservoirs of the aquatic resource is inherent in any such principle.

Given policy goals and the strategic objectives which follow from them, management is essentially a decision-taking task. The information, knowledge and wisdom applied to decision-making are based on available data.

Data should not be confused with information. Data comprise the collection of facts, observations, etc., which require editing, processing, interpretation and communication before they may be considered as usable elements of information.

The manner in which such information is conveyed to the user essentially and effectively controls the degree to which one receives, understands and accepts the information as knowledge. Wisdom comprises the collection of techniques and ability to use or apply knowledge in an intelligent manner through the use of judgement, insight and experience.

My definitions of these terms follow their usual use in the information science community.

Too often overlooked is the fact that unlike most other resources, fish stocks cannot be contained within political boundaries; they are not visible in the usual sense of the word and their assessment must be made by indirect means. These indirect means require varying amounts and kinds of data. Convincing administrators and planners of the importance and fundamental need for programmes to obtain this information prior to any other more

"visible" projects is the most difficult task facing the fishery manager today. Most failures in fishery development programmes are traceable to the lack of adequate resource assessment data and parallel economic information.

The Attributes of Data and Information

The characteristics of information have been communicated in a variety of publications and most succinctly in fisheries in an ACMRR report of 1974. These attributes are:

Scope and Relevance
Timeliness
Accuracy and Precision
Clarity and Ease of Comprehension
Acceptability and Credibility

Management is perceived as a wide variety of activities depending on the client or user. It is fundamental and essential that management and planning proceed in an hierarchical fashion if the data are to meet the criteria of scope and relevance, timeliness, accuracy and precision (see annex for definitions of last two terms). As an example, because the degree of uncertainty among several elements is additive, if several elements contribute to a final decision which should be correct to 10 percent then each element must be collected with substantially less than 10 percent error. If the data are dependent upon a variety of sources which can only be collected at some gross level of measurement the result will be accordingly affected. The failure to look at the cost and benefit of incremental improvement of varying levels of accuracy on overall need results in programmes where some data are collected to several decimal places and then combined with other data comprised only of gross guesses. Unhappily, this is the usual case! It is to be emphasized that these same statements relate to timeliness with equal if not more validity. However appropriate, knowledge unavailable for decision-making because it is still in the process of analysis is for all purposes useless.

Different kinds of data are required for understanding of stocks, harvest, processing, distribution and marketing. Though each need specific input their purposes are parallel.

There are four common uses of data in the fisheries area. These uses tend to match the type of the input data as well.

The four categories of management information and implied priorities are: (the examples given reflect only the stock and harvest sectors.)

1. Immediate Management - the monitoring of the activity against the objective or goal. This comprises primarily the measurement of rates of removal by measuring effort and catch. It is to be emphasized that the operative word here is catch and not landings. This information requirement has a continuing need for data on an up-to-date basis.

2. Safe-Fail Information - the ability to determine the state of the resource; when rapid cessation of an activity should be enforced and alternative or contingency plans implemented. The data required to monitor the state of the resource may include information such as stock size and extent of spawning, recruitment, mortality rates and/or environmental factors such as pollution. Data acquisition usually requires some form of standardized survey approach. I distinguish between safe-fail and fail-safe in that the former allows one to recover to the original state whereas the latter only assures that one does not get further into trouble. Their differing data requirements are substantial. Both involve continuous data acquisition programmes.

3. Remedial, Improvement and Enhancement Activities - data which involve a wide variety of environmental technical information. Data needs usually are intermittent and usually not required for an extended continuing basis.

4. Research and Development - data acquisition which covers the broad range of fundamental and applied research in fisheries designed to solve problems existing within the previous three categories.

The appropriateness of these categories becomes clear when considering the requirements of data in terms of relevance, timeliness, accuracy and precision to information needs. From a statistical viewpoint, the selection of data needs is particularly revealing in the manner in which these categories reflect a breakdown into enumerative and analytical components. As Deming (1975) stresses, the confounding of these two data types in terms of predictive accuracy continues to elude many statistical texts.

There is an urgent need for the development and application of sampling techniques and estimates of variance whereby when the given level of precision is reached the programme can be stopped. Some information is required on a continuing basis but in many other cases through failure to express a desired level of accuracy and precision, data collection continues on "forever". The professed need for more study and data has contributed to the frequently existing credibility gap between the fishery scientist and senior managers for which the scientist is often responsible. It is important to know when to terminate a programme in terms of return on data improvement. All of the previously mentioned problems require knowledge of the inherent variability of the data. The concept of variance is central to data acquisition.

Data/Information in Industry and Fisheries - The-State-of-the-Art

The evolution of contemporary handling of data and information has proceeded through three phases: data processing, management of information, and resource information systems. While these categories merge into each other and are not considered separate by some, it is generally accepted that data processing is not information processing. Chronologically most industrial/commercial fields have survived the trauma of converting from hand or other primitive means of processing data and have either passed on to management information systems or are in the state of developing advanced "resource" information systems.

Data processing consists of the editing, standardization, documentation, reduction and report generation of the input material. It should be recognized that while data are ordinarily defined as facts, frequently input data from the fishery are observations or interpretations. It is important to differentiate between these two basic sources.

It is as important to know what data are available as well as to know what information is not. The purpose of a data base is to aid decision-making and to provide for the substantiation of administrative opinions and resulting decisions to the manager's constituents, both senior and junior. Implementation of computerized data processing systems in fisheries have a number of demonstrated advantages, the most important being a significant reduction in the existing time lag between data acquisition and its use in decision-making.

A data base management system usually comprises a computerized integrated system of data and programmes for organizing, documenting, storing, manipulating and retrieving data. The usual approach to the problem is to use relational concepts. A relation is a specific way of logically organizing data which permits retrieval of all elements bearing a given "relation" to each other.

Since natural resources do not recognize political boundaries and because of the interdependence of the world with respect to natural resources there is a fundamental need for standardization of input information so that comparisons among nations are possible. Currently most fishery information systems are not compatible with one another. In environments marked by high personnel turnover and a need to share or collate data from several sources, the need for careful data documentation must be emphasized.

Perhaps the fundamental impediment to the development of adequate information systems in fisheries has been the almost universal failure to assess data requirements in terms of

accuracy and timeliness on a cost-benefit basis. The techniques to evaluate costs of information in terms of their inherent variability and resultant utility in decision-making are reasonably well developed; they are used widely in many segments of industry.

The primary difference between the industry/business community and the fishery arena in their respective uses of data processing is the degree to which automatic report generation is utilized in the decision-making process. There are frequent delays in the communication process between the development of information and its use by fishery administrators. The-state-of-the-art is simply not being capitalized upon in fisheries.

Another area of information hiatus is in industry-fishery management agency relationships. There is a reluctance on the part of industry on both the primary and secondary levels to provide the necessary data with sufficient resolution and timeliness to aid the fishery management process. There is need to develop industry trust on a much broader basis than now exists. Without trust there can be no cooperation. In this regard every attempt should be made to separate data gathered for tax purposes from those required for resource management. At a minimum the information should be collected by different organizations. This is a particularly important problem in the artisanal segment of the "industry".

Since resource management is largely for the benefit of people, the data requirements of fishermen are an integral part of the management process. Information for economic planning frequently can be obtained in cooperation with industry. Primarily the need is for information involving price, sales and distribution of catch and to a lesser extent, long term information on stock size and availability to permit future planning by the industry group or individual fishermen. The former knowledge is currently available in a variety of measures but none as extensive or useful as those presently employed by the agricultural sector. In many countries, daily or weekly lists of current fish prices are available to the fishermen. What is needed would be a broadcast service comparable to the "farmers' programme" that would give prices in "real time" by port of landing or distribution centre. Included in such information might be local weather, trends in catches, regulatory information, etc. The use of radio in agriculture has been well established and current experiments providing selected information on satellite TV channels offer some exciting challenges as well as problems. The general lack of such services to fishermen is lamentable. Another type of information, while not required for management in a direct sense, but critical for gaining the long-term cooperation of fishermen is information on what the government, particularly research and management bodies are doing. The greatest frustration expressed by fishermen is their feeling of non-involvement and lack of information. Providing a mechanism of communication with fishermen would do much to correct this kind of alienation. It has been argued that fishermen are not interested in the conservation of their resource. This may be true at the lowest abject levels of poverty but certainly a common feeling of fishermen throughout the world is that as soon as he achieves any financial security, the fate of his resource becomes a primary concern after his family.

Aquatic sciences are not alone among resource sciences in their difficulties in approaching the data processing and management problem. The geological fields have experienced a similar evolution though their progress appears to be greater (e.g., the series of papers in the Journal of the International Association of Mathematical Geology, Vol.9, 1977).

Only the forerunners of the business field have progressed to the consideration of the third generation or "resource" information systems. In its simplest form this concept involves more than information retrieval systems but connects the appropriate information with the pertinent user, updates the information as necessary and in its idealized conception provides for an interactive dialogue between user and the information base. The concept is in its earliest stages of development in industry and to my knowledge does not exist in a comparable form in the fisheries realm.

It is unlikely that much progress can be made in this third phase of information use until many more regional bodies and national fishery organizations proceed farther into the second stage with the resultant development and acceptance of standards and documentation. Without some common protocol, transfer of information even within a single organization is impeded if not completely halted. It is not uncommon to find information systems in the most advanced nations which are totally incompatible with each other even though they are supposed to provide information to common users.

Summary and Priority Concerns

Because of their fundamental importance in decision-making and support, consideration should be given to the following problems in the data-communications area of fishery science. The first two elements are considered of equal priority.

1. Base Data Acquisition

A. The training in methods of implementation and the expansion of existing systems of collecting data on catch, effort, and value (revenue and costs) to encompass all fisheries.

B. The development and implementation of incentives to primary fishermen to report basic data on catch, effort and value.

C. Preparation of an inventory of unpublished data by species whether or not the raw data are available for distribution outside the institution or country holding the data.

2. Communication of Information to the Users

Conversion of raw data to accurate, timely, acceptable information in a form useful to the various categories of users is a paramount problem in fishery communication.

3. The Cost of Uncertainty

The methods of comparing the costs of acquiring data with its value to management or the cost of not having such information are analytical tools needed by most fishery organizations and training in these methods is required. In general the technology for such comparisons exists but has only been rarely applied in fishery science. The demonstration of this "cost of uncertainty" could play a significant role in solving the goals of priority 2.

4. Development of Data Processing Systems for Fisheries

The many advantages of computerized data systems warrants their wider use. However, there is urgent need for agreement on standards, documentation, editing procedures and the distribution of computer programmes (written in high level languages so that they are independent of individual computer systems) to carry out basic analysis and report preparation of fundamental fishery statistics. The experience of the United Nations statistical office in similar activities for the terrestrial sciences should be examined for their relevance to fishery needs.

5. Development of Appropriate Sampling Systems

Development and application of sampling systems, including estimation of variance, appropriate to a variety of fishery requirements could substantially reduce the cost and extent of data acquisition programmes. Training in developing sampling programmes and preparation of suitable manuals and data reduction programmes could do much to circumscribe sampling problems in a manner acceptable to senior administrators and supporting agencies while providing sufficient accuracy and precision for most management uses.

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Annex

Error and Uncertainty

The following definitions drawn from several standard references are relevant to discussion of fishery data.

Mistake: a departure from the correct, prescribed or intended procedure. For example, a mis-reading, faulty adjustment or miscalculation in arithmetic.

Error : the departure of a measured value from the true value. 'True' values for most natural constants reflect the state-of-the-art of measurement. In the biological context individual animals are not genetically identical and 'error' is frequently synonomous with individual variability.

Experimental Error

Systematic Error: regular and predictable effects, usually of constant sign and may be periodic. Repetitive readings may give no clue as to the presence of systematic errors. They may be due to the use of incorrect constants or measurements that are consistently slow or fast/short or long. Such bias, whether mechanical or personal depends upon a standard to be detected. A particular form of bias known as digit bias affects measurements (e.g., people prefer 0.0 or 0.5) but once discerned usually can be corrected through a change in measurement techniques. Bias is any consistent deviation between the true population parameter and repeated estimates based on the sampling design.

Random Error: errors without pattern usually following a normal distribution. They are irregular in magnitude and sign. Extreme random errors are frequently called erratic errors or outliners. Random errors in some works are classified as accidental errors.

Precision: is a measure of the resolution of a measurement expressing the range of statistical uncertainty, i.e., the smallness of the region of random errors; the degree to which reproducible results are possible. It is the degree of control that one has over measurement and is expressed by standard deviation, variance, coefficient of variation or range. Precision refers to the size or range of the deviation of the sample from the mean. A high precision results from low variance and low precision from high variance. Precision is the variability of successive estimates about their mean when a sampling design is repeated on the same population.

Accuracy: represents the closeness or nearness to 'the true value' and is related to systematic error. It is usually expressed in terms of mean error or relative error. Accuracy refers to the size of the deviation of the measured value from the true value.

Reliability: the statistical characteristics of a measure expressed as the probability or likelihood of a measurement being correct; an imprecise term.

APPENDIX 7

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